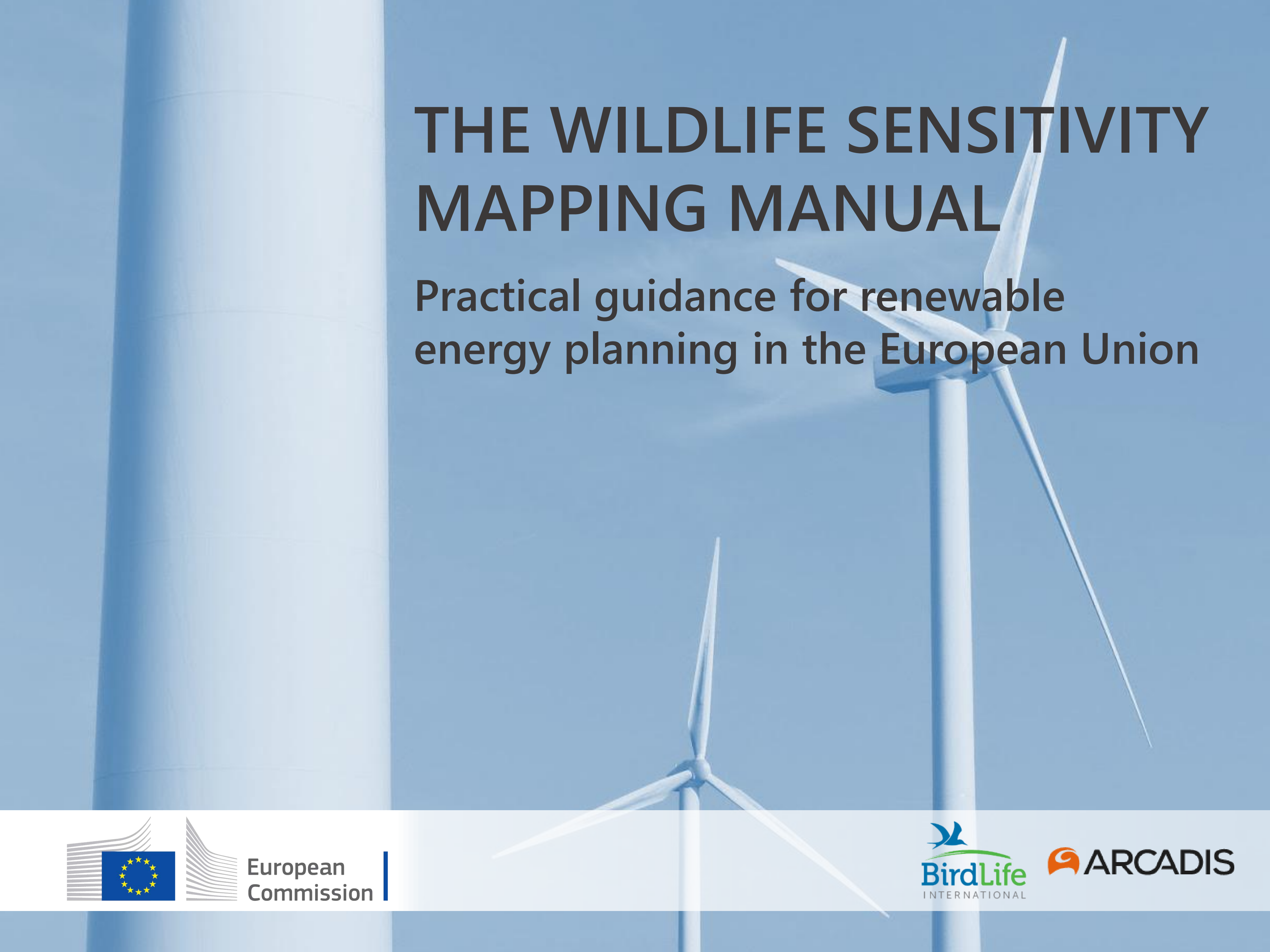

THE WILDLIFE SENSITIVITY MAPPING MANUAL

Practical guidance for renewable energy planning in the European Union

European Commission

BirdLife INTERNATIONAL

ARCADIS

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Available to download at:
https://ec.europa.eu/environment/nature/natura2000/management/natura_2000_and_renewable_energy_developments_en.htm

HOW TO USE THE MANUAL

This manual is an interactive tool. Users can navigate the content using the icons on the navigation bar or by following links from the various section and sub-sections headers. In this respect the manual is designed much like a website. As with a website, all content is only ever a few clicks away and the content need not be read sequentially.

The manual is intended as a comprehensive compendium of the information necessary to develop wildlife sensitivity mapping approaches to inform renewable energy deployment. As such, it contains extensive links to external websites and documents which provide further in-depth information and examples. Linked content is clearly delineated through the use of icons, whilst all blue text links to additional content.

Icons

Icons are used throughout this manual to aid navigation.

Previous view

For ease of use add the "previous view" button to your PDF viewer. In Adobe Acrobat you can do this by right clicking on the toolbar, select page navigation tools and make sure that there is a tick next to "previous view". This will add a back button to the toolbar. Pressing alt+right arrow provides the same function.

CONTENT

Purpose of the manual

The European Union has adopted one of the most ambitious renewable energy policies in the world. Restructuring Europe's energy sector along renewable lines whilst ensuring compliance with EU nature legislation requires careful and early stage spatial planning in order to avoid creating new hazards for wildlife. As part of a wider study on the impacts and available mitigation measures in the interplay of renewable energy sources and EU protected species and habitats[1], specific attention has been paid to a key instrument in this context, which is wildlife sensitivity mapping. In wildlife sensitivity mapping, spatial biodiversity data, Geographic Information Systems (GIS) and wildlife sensitivity assessment approaches are employed to identify areas where the placement of renewable energy could adversely impact the wildlife protected by the EU Nature Directives (**Directive 92/43/EEC, the Habitats Directive; Directive 2009/147/EC, the Birds Directive**) and should therefore be avoided or mitigated.

This manual provides a comprehensive overview of the datasets, methodologies and GIS resources needed to develop effective wildlife sensitivity mapping approaches within the EU. The manual draws together the information needed to develop such approaches for renewable energy technologies. The focus is on a number of key wildlife attributes; these include all species and habitats protected by the EU Nature Directives, with particular emphasis on birds, bats and marine mammals. The manual includes key recommendations relating to the most suitable data types and sensitivity analysis.

NOTE The manual aims to equip EU governments and other relevant parties with the foundational information necessary to develop robust wildlife sensitivity mapping approaches for renewable energy. The strategies and recommendations outlined are in no way intended as prescriptive, but rather as a useful resource to support effective adherence to EU nature legislation.

[1] SERVICE CONTRACT FOR REVIEWING AND MITIGATING THE IMPACTS OF RENEWABLE ENERGY DEVELOPMENTS ON HABITATS AND SPECIES PROTECTED UNDER BIRDS AND HABITATS DIRECTIVES, CONTRACT NUMBER - 07.027733/2017/768654/SER/ENV.D.3

Overview of wildlife sensitivity mapping

- General characteristics and definition
- The planning and development process
- Step-by-step approach to wildlife sensitivity mapping
- Recommendations

Overview of wildlife sensitivity mapping

General characteristics and definition (1/2)

Wildlife sensitivity maps are recognised as an effective tool for identifying areas where the development of renewable energy might impact sensitive communities of wild plants and animals, and thus should be avoided.

Wildlife sensitivity maps have the following broad characteristics:

- They are used to identify at an early stage in the planning process areas containing ecological communities sensitive to a specific influence or activity, (for the purposes of this manual, the focus is specifically the construction, operation and maintenance of certain renewable energy infrastructure).

- They typically inform strategic planning decisions during the initial site selection phase of the development process and therefore are intended to operate at a landscape scale, often with regional, national or multi-national coverage. As such, wildlife sensitivity mapping approaches **DO NOT replace the need for site-specific Appropriate Assessment under Art.6 of the Habitats Directive and Environmental Impact Assessments (EIAs)**. They can, however, also be used during EIAs and post-consent to inform micro-siting and possible management prescriptions.

- They use Geographic Information Systems (GIS) to collate, analyse and display spatial and geographic data.

- They employ spatial biodiversity data relating to species and/or sites. They often use existing biodiversity datasets; however, sometimes data are collected explicitly for the creation of a wildlife sensitivity map.

- Most approaches go further than simply displaying spatial datasets—site boundaries, species ranges and records,

Overview of wildlife sensitivity mapping

General characteristics and definition (2/2)

geographic features—and assign sensitivity values derived from the data.

- They are predictive, providing a forecast of potential sensitivity at one or more sites, or across a wider landscape, based on the best available data and an exercise in mathematical and graphical modelling. As such, wildlife sensitivity maps should be interpreted with caution.

Overview of wildlife sensitivity mapping

The planning and development process

The scale and speed of the renewable energy revolution, combined with the inherent interconnectivity of energy networks, necessitates strategic planning at a national or even regional cross-border level. This should include the spatial assessment of potential conflicts with biodiversity and other environmental objectives as part of a regional or national (or even supra-national) Strategic Environmental Assessment (SEA) including an Appropriate Assessment for any Natura 2000 protected areas. It is at this initial, landscape-scale assessment stage that wildlife sensitivity mapping is most appropriate. Such an approach can radically reduce the likelihood of wildlife conflict, as well as reducing uncertainty and cost to developers.

The vast majority of wildlife sensitivity mapping exercises to date relate to wind power, and to a lesser extent, solar power. These technologies are particularly appropriate for strategic landscape planning. Both wind power and solar radiation are generally widespread resources. There is, therefore, considerable geographic flexibility in their siting and considerable opportunity to avoid locations where the likelihood of conflict with wildlife is high. Geothermal power offers less geographic flexibility, but will still benefit from landscape-scale spatial planning. To date, there has been little wildlife sensitivity mapping in relation to ocean energy, reflecting the infancy of these technologies; however, given the spatial distribution of wave and tidal resource and the high biodiversity value of marine ecosystems, sensitivity mapping techniques are likely to become increasingly important.

Once a location or number of locations have been identified as potentially suitable for a renewable energy development, early screening should be undertaken in the context of Environmental Impact Assessment (EIA) and related Natura 2000 provisions to identify potential risks. Wildlife sensitivity maps can again be consulted at this stage to aid in the final selection of location. When a location has been selected for development, wildlife sensitivity mapping can also be used to better inform and corroborate an impact assessment.

Overview of wildlife sensitivity mapping

Step-by-step approach to wildlife sensitivity mapping (1/3)

1. **Identify the renewable energy types to be included and the species and habitats likely to be affected**
   What renewable energy infrastructure will be included (wind, solar, geothermal, ocean)? What species or habitats are likely to be affected? How are they likely to be affected?

   Affected species / habitats
   - Consider species / habitats likely to coincide with development (at any stage of lifecycle) – and consider all life history phases (breeding, migration, non-breeding etc.).
   - Consider different phases of development (e.g. construction, operational phases) as well as associated infrastructure (e.g. implications of grid connections with transmission lines).
   - Consider which species / habitats are sensitive to development (characteristics, population dynamics).
   - Consider which species / habitats are of conservation concern (e.g. those listed within the Birds and Habitats Directives).

   Likely impact
   - Consider how species are impacted: Habitat loss and degradation, collision with infrastructure, avoidance, displacement and barrier effects.

Natura 2000 and renewable energy developments

Overview of wildlife sensitivity mapping

Step-by-step approach to wildlife sensitivity mapping (2/3)

2. **Compile distributional datasets on sensitive species, habitats and other relevant factors**
   Review what distributional data are available and consider whether additional data should be collected.
   - In case the datasets are spatially incomplete, consider whether it will be necessary to use modelling, based on habitat and landscape predictors, to forecast distribution in under sampled localities (e.g. Density Surface Modelling).
   - It is also important to openly highlight data deficiencies and other methodological shortcomings.

3. **Develop a sensitivity scoring system**
   Assign sensitivity scores to species and habitats based on identified characteristics (species behaviour, habitat fragility, conservation status etc.).

4. **Generate the map**
   What is the most appropriate mapping format and GIS software? What is the most appropriate mapping unit?
   - Generate a grid based on an appropriate mapping unit and overlay the species distributions (or models) and potentially other useful datasets, including relevant buffer zones.
   - Identify the species present within each grid cell (i.e. where a species location (or part of a buffer) is included within a grid square).
   - For each grid square calculate a score using the species sensitivity scoring system.

5. **Interpretation**
   How do the sensitivity scores relate to risk? How should the map be interpreted?
   - Group sensitivity scores in categories indicative of their level of sensitivity (e.g. very high, high, medium, low). Where

Overview of wildlife sensitivity mapping

Step-by-step approach to wildlife sensitivity mapping (3/3)

data gaps exist in may not be advisable to assign areas as having 'low' sensitivity. In such circumstances, it may be preferable to use the terms 'unknown' or 'uncertain' sensitivity. On occasion, categories are chosen that indicate a particular prescription (e.g. no-go areas vs. low risk areas).

- Develop guidance material to sit alongside the map that fully explains what data are used, how the map is generated, how it should be interpreted and what caveats exist regarding the interpretation.

Overview of wildlife sensitivity mapping

Recommendations (1/2)

1. Wildlife sensitivity maps should be a standard precursor to all renewable energy plans and development.

2. Wildlife sensitivity maps should be developed in close collaboration between all relevant stakeholders including regulatory authorities, wildlife organisations and developers.

3. Many Member States will be considering a renewable energy mix that includes elements of wind, solar and other technologies. Ideally, these different renewable energy types should be considered collectively through the same mapping exercise with sensitivity layers developed for each type separately.

4. Wildlife sensitivity maps should be undertaken at a variety of geographic scales. Planning at a large spatial scale is essential in order to strategically optimise the most appropriate development opportunities both from renewable energy perspective and a nature perspective. Where possible, maps should be developed at a regional, national or even a multinational level. However, finer-scale maps, informed by additional data collection, and targeted at areas of either high development potential or high likelihood of wildlife conflict, should also be considered.

5. Wildlife sensitivity maps should attempt to cover all potentially impacted species and habitats of conservation concern (inclusion within the EU Nature Directives). Certain taxa will inevitably prove more difficult to assess with limited data on their distribution and incomplete knowledge on how they are impacted. Such groups will require more rudimentary analysis and a more precautionary interpretation.

6. Where possible, wildlife sensitivity maps should be designed to be compatible with existing planning tools.

Overview of wildlife sensitivity mapping

Recommendations (2/2)

7. Wildlife sensitivity maps should be publicly accessible, simple and intuitive to use and accompanied with clear interpretative guidance.

8. Wildlife sensitivity maps should be developed in collaboration with multiple taxonomic experts to ensure the comprehensive compilation of relevant datasets.

9. Datasets relating to the Natura 2000 network can be used to develop wildlife sensitivity maps in the EU. Data collected in association with Articles 12 and 17, based on a 10 x 10 km grid, can provide a good basis for data generation.

10. Wildlife sensitivity maps should be developed in such a way that new datasets or updates can readily be incorporated.

11. Data on broad habitat suitability can be a useful starting point for data deficient taxa. Data (and knowledge on how best to interpret it) is much more limited for certain taxa such as bats and marine mammals.

12. Wildlife sensitivity maps should utilise the best available data at the finest possible scale. They should clearly indicate levels of uncertainty, data limitations and the comparability of different datasets.

13. Wildlife sensitivity maps should be compatible with the relevant planning system and be accessible to all relevant users and target groups. Online platforms are a good way to present maps, enabling end user to interactively interrogate the maps and view the layers alongside other variables, such as other development locations, protected sites etc. Face-to-face promotion with planning authorities, developers and other end-users can be valuable in increasing uptake.

Wildlife sensitivity map development

- Compiling and preparing datasets
- Develop a sensitivity scoring system
- Mapping resource, transmission and constraints
- Geographic information systems (GIS) and map presentation

Wildlife sensitivity map development

Compiling and preparing datasets (1/3)

Spatial datasets on the distribution and abundance of wildlife exist in many formats and are typically generated for purposes other than the creation of wildlife sensitivity maps (e.g. atlas surveys to examine species distribution range, GPS tracking to assess detailed movements of individuals). Seldom are data collated specifically for sensitivity mapping or are the datasets readily available in a suitable format for inclusion within a mapping tool. Wildlife sensitivity maps are typically based on a grid, with the chosen resolution (i.e. the size of grid cells) designed to enable meaningful interpretation of wildlife data in the context of renewable energy development. Therefore, in most cases, the data must first be manipulated to comply with the chosen grid. In this respect, point-based data extracted from transect or GPS-tracking type surveys are often easier to adapt compared with polygon data (e.g. atlas grid, species range maps) where the resolutions may not match. Most GIS software include tools that overlay and join point data to the relevant grid cells, or that clip polygon data based on the grid.

Often distributional wildlife data is not generated through systematic surveys and is heavily biased towards sampling effort and intensity. There are however analytical approaches that enable the manipulation of such datasets to account for sampling effort and the following analytical techniques are frequently applied to spatial datasets prior to inclusion in wildlife sensitivity mapping tools:

Estimating densities from point or line-transect data

- **Distance sampling**: Used for estimating density or abundance from point or transect data, where the distance between the observer and the animal has been recorded (or attributed to distance bands) (Buckland *et al.* 2001). Generally, the probability of detecting an individual decreases with increasing distance from the observer, and distance sampling is based on detection functions, which model the probability of detecting an individual, given its distance from the transect. This concept is fundamental to the development of Sensitivity Surface Models.

Wildlife sensitivity map development

Compiling and preparing datasets (2/3)

Predictive modelling for generating estimates for unsampled locations

- **MaxEnt**: Used for generating Species Distribution Models (SDMs) where survey data tend to be sparse and/or limited in coverage, and species records are available in the form of presence-only records. (Phillips *et al.* 2006). See

- **Regression methods** (e.g. generalized linear, mixed or additive models, GLMs, GLMMs or GAMs; or ensembles of regression trees: random forests or boosted regression trees): Used to develop SDMs which estimate the relationship between species records at sites and the environmental and/or spatial characteristics at those sites, where species data have been collected systematically, e.g. in formal biological surveys in which a set of sites are surveyed and the presence/absence or abundance of species at each site are recorded.

- **Density Surface Modelling**: Fits a density surface model (DSM) to detection adjusted counts from a spatially-referenced distance sampling analysis. It allocates observations of animals to segments of line (or strip transects) and adjusts the counts based on detectability using a supplied detection function model. A generalized additive model, generalized mixed model or generalized linear model is then used to model these adjusted counts based on a formula involving environmental covariates. A DSM can be used to predict abundance over a larger/different area than was originally surveyed. See

Modelling future changes in species distribution due to climate change

The distributions of many species are predicted to alter in response to climate change. If data is available to model future distributions under different climate scenarios, this information could be integrated into a sensitivity mapping approach. Whilst such modelling exercise may not always be feasible, shifting distributions, not least as a result of climate change, are an

Wildlife sensitivity map development

Compiling and preparing datasets (3/3)

important consideration and a reason why sensitivity maps should be updated regularly.

Wildlife sensitivity map development

Develop a sensitivity scoring system (1/8)

Some wildlife sensitivity maps simply present biological data visually and leave the interpretation of the data to the end-user. However, in most cases, merely knowing the geographic extent of a biological feature, e.g. the range of a vulnerable bird species or the location of a bat roost, is of limited value. What is also needed, is interpretation that shows what the incidence of a particular biological feature means in terms of the prospect of renewable energy development.

The simplest interpretation is to collectively assign all data layers as sensitive. The only explanatory embellishment might be to buffer features to represent dispersion (for instance, known dispersal from a roost site) or in recognition of uncertainty over the accuracy of the data. It might be that some features, for instance a vulture colony, receive a buffer of many kilometres, whilst others, such as some bat colonies, receive a smaller buffer.

Buffer zones should be determined:

- With reference to established protocol used in similar approaches elsewhere.
- With reference to known biological parameters as reported in the literature (for instance the documented range size of a particular breeding bird species).
- In a precautionary manner that recognises data and knowledge limitations.

In some approaches, all sensitivity features, and any associated buffers, are described as ‘no-go areas’, in which zero development is recommended. However, the majority of wildlife sensitivity mapping approaches avoid such an absolute prognosis in recognition of the limitations of both spatial data and mapping techniques. Indeed, in some, albeit limited, circumstances it may be possible to sufficiently mitigate impacts even at highly sensitive locations such that development can proceed.

Wildlife sensitivity map development

Develop a sensitivity scoring system (2/8)

Most wildlife sensitivity maps approaches provide a gradient of sensitivity. At its simplest, this can entail classifying certain core features, such as protected areas, as no-go sites and less sensitive, secondary locations, as sites where development could prove problematic and where caution is advised. More complex mapping exercises assign sensitivity by weighting features in relation to known parameters that increase sensitivity. Factors that enhance sensitivity generally fall into the following categories: species characteristics, habitat characteristics, population dynamics and conservation status.

Species characteristics

- *Species behaviour*: some species are more sensitive to renewable energy development due to certain behavioural traits. Degree of exposure may be the most significant factor underpinning a species' sensitivity. For instance, those bird and bat species most likely to collide with wind turbines are likely to be those that spend the most time flying at a height corresponding to the rotor sweep zone, roughly between 30 – 150 m above the ground.

- *Species morphology*: certain species may be more sensitive due to their morphology. For instance, bat species with wings designed for fast flight in open spaces are more susceptibility to collision with wind turbines. In birds, wing loading (the relationship between wing area and body weight) is also regarded as a key factor governing collision risk. Eye structure may be equally key, for instance, the visual field of *Gyps* Vultures contains a small binocular region and large blind areas above, below and behind the head, which may render them frequently sightless in the direction of travel.

- *Migratory behaviour*: certain species may be more sensitive due to the nature of their migration. For instance, some species migrate along well defined routes and thus occur in high concentrations. If renewable energy infrastructure is located along these routes, especially at key bottleneck sites, the likelihood of impact is increased.

Wildlife sensitivity map development

Develop a sensitivity scoring system (3/8)

Habitat characteristics

- *Habitat fragility*: certain habitats are more sensitive to renewable energy developments.
- *Habitat dependence*: certain species are dependent on a limited range of habitats and could be jeopardised if too great a proportion of that habitat is exposed to development.

Population dynamics

- *Proportion of global/regional/national population*. The larger the proportion of a population that would be affected, the greater the sensitivity.
- *Life history traits*. Direct mortality, such as that resulting through turbine collisions, are more likely to result in population level effects in species which display traits associated with slower rates of reproduction and higher reliance of adult survivorship.

Conservation status

- *Global, EU, regional or national conservation status*. Species of conservation concern, such as those listed as globally threatened on the IUCN Red List, national Red Lists or the EU Nature Directives are particularly important to identify.

Wildlife sensitivity map development

Develop a sensitivity scoring system (4/8)

Once a list of at-risk species and habitats has been created, these can be scored in terms of the level of their sensitivity. Such lists should be based on a thorough investigation of the scientific literature and through consultation with key experts. The scoring of parameters, such as flight height or collision avoidance rate, should be based on experimental evidence. However, this will not always be possible and it may be necessary to extrapolate from known parameters for closely related taxa. It should be noted that behaviours and responses can vary significantly even among taxonomically close species.

Theoretical example of a sensitivity scoring system

In this simple, theoretical example, four species are scored in relation to their sensitivity to a form of renewable energy. The spatial distribution of the four species is fitted to a grid system. Within each grid square the scores of those species present are summed to create an overall score for each grid cell and therefore a rudimentary sensitivity map.

STEP 1:
The four species are scored in relation to the morphological, behavioural and population dynamic traits that enhance their sensitivity and their conservation status. These scores are then summed to produce an overall sensitively score (see example scoring system). In this example, species regarded as highly or very highly sensitive in relation to one parameter are automatically placed in the 'HIGH' category irrespective of how they score for other parameters.

Wildlife sensitivity map development

Develop a sensitivity scoring system (5/8)

Morphology / behaviour / population dynamics score: (1=Low sensitivity, 2=medium sensitivity , 3=high sensitivity, 4=very high sensitivity).

Conservation score: (0=Low, 2=medium , 4=high, 6=very high).

SENSITIVITY SCORE: MEDIUM (3-8) HIGH (9-14) VERY HIGH (15-20)

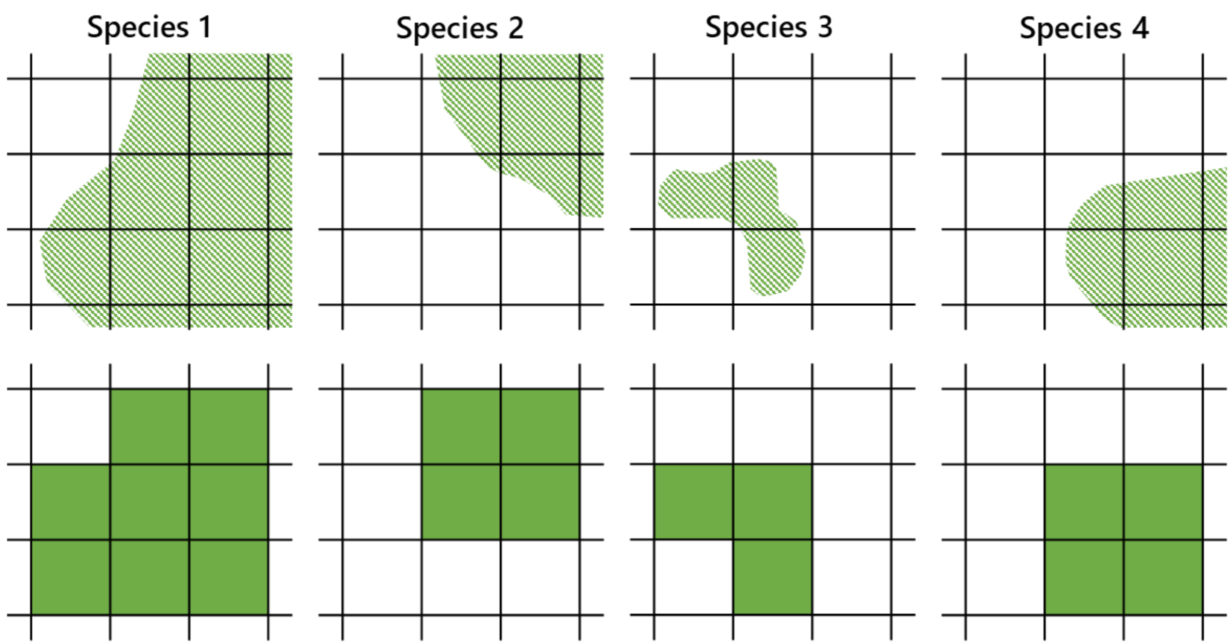
(Any species scoring 3 or 4 for morphology / behaviour / population dynamics is automatically in HIGH category)

Species	Morphology	Behaviour	Population dynamics	Conservation status	Sensitivity Score
Species 1	3	1	1	0	5
Species 2	2	2	2	0	6
Species 3	4	2	1	6	13
Species 4	4	4	4	6	18

Wildlife sensitivity map development

Develop a sensitivity scoring system (6/8)

STEP 2:
Spatial data on the distributions of the four species are then fitted to an appropriate grid system.



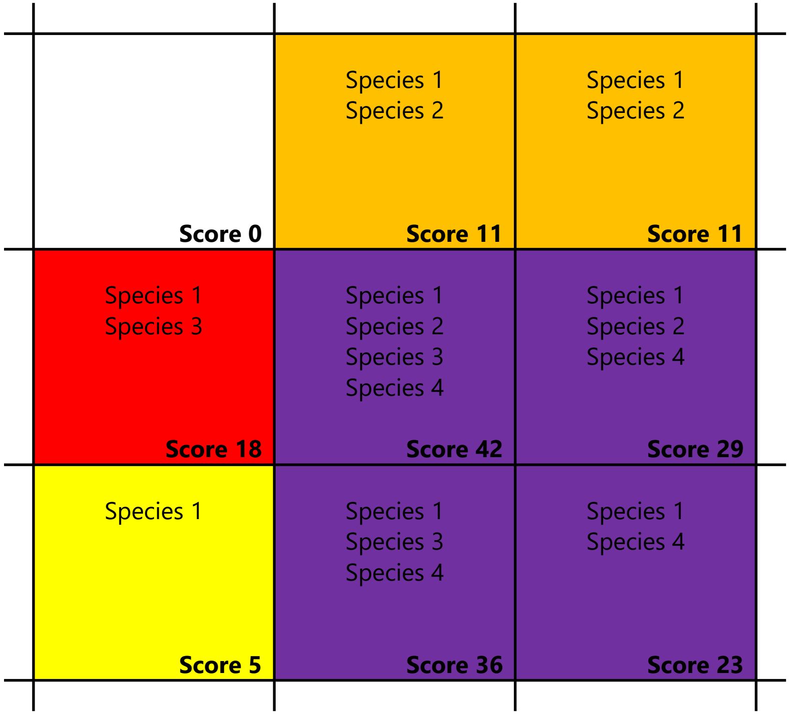
Wildlife sensitivity map development

Develop a sensitivity scoring system (7/8)

STEP 3:
Combined sensitivity scores can then be applied by summing the sensitivity scores for each species present within a grid square, thus producing an overall score for each gird cell.

The figure depicts a theoretical grid weighted in accordance with the previous sensitivity scores. This simple example is based on presence / absence; however, where population data is available, this can be used to weight each grid square in relation to the number of individuals per species or the proportion of the global or regional population of each species present.

Sensitivity Score MEDIUM (3-8) HIGH (9-14) VERY HIGH (15-20) EXTREMELY HIGH (>20)

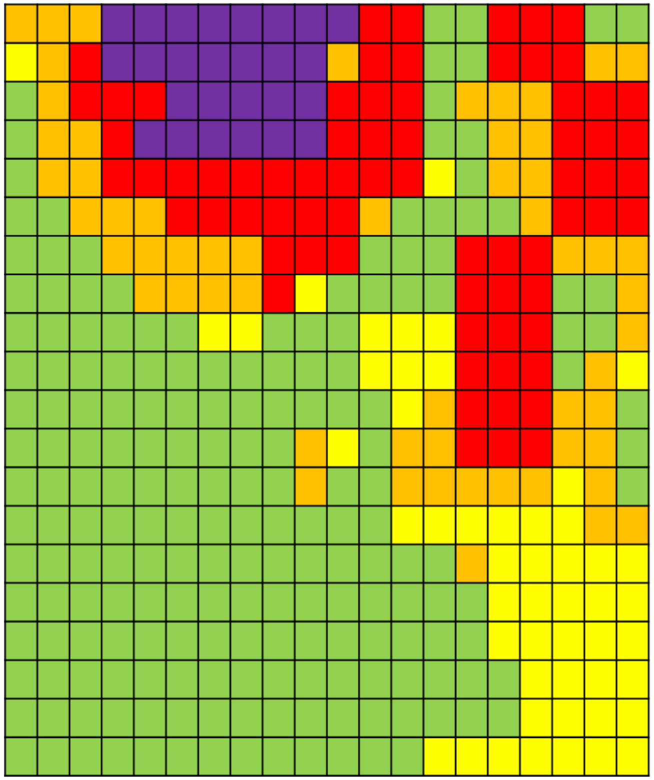


Wildlife sensitivity map development

Develop a sensitivity scoring system (8/8)

STEP 4:
The final sensitivity map depicts combined sensitivity in relation to four theoretical species across a theoretical landscape. In such maps, sensitivity levels are typically depicted using different colours.

- EXTREMELY HIGH (>20)
- VERY HIGH (15-20)
- HIGH (9-14)
- MEDIUM (3-8)
- LOW OR NONE (<2)



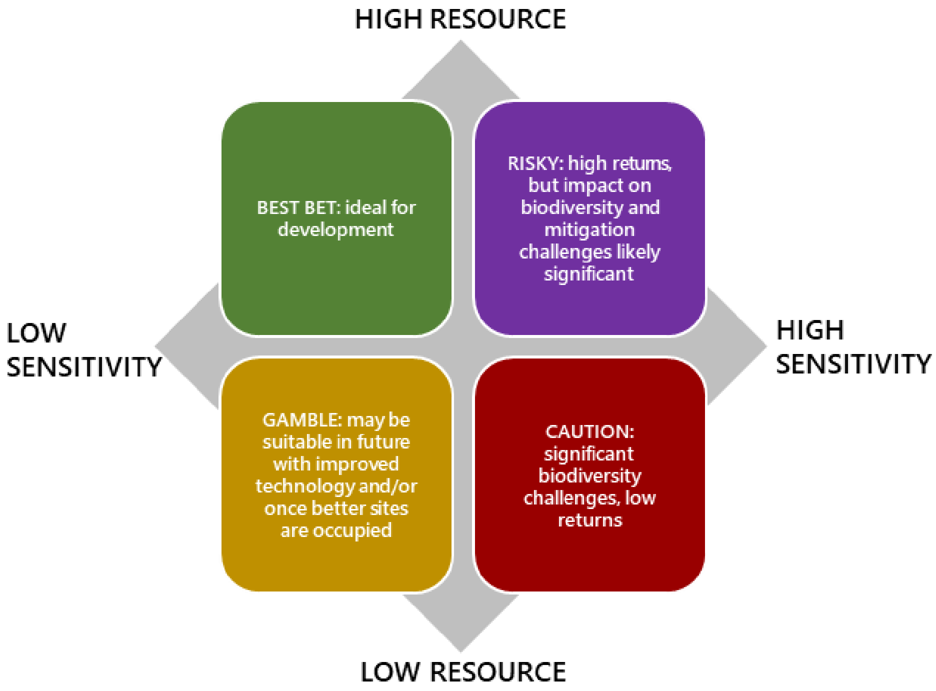
Wildlife sensitivity map development

Mapping resource, transmission and constraints (1/3)

Wildlife sensitivity maps can be further developed to incorporate other factors determining the placement of renewable energy.

They can be combined with renewable resource maps to identify sites that are both high in renewable resource but low in wildlife sensitivity and therefore optimal for development (see figure).

Other spatial considerations include connectivity to the transmission grid, pre-existing land uses and political, legal and social constraints. From a planning perspective there is considerable value in developing maps that can be easily integrated with resource and constraints information to produce a combined map of overall suitability. Stakeholder consultation is a good method for identifying the range of economic, cultural, and environmental activities and features that may represent constraints to renewable energy development.



Wildlife sensitivity map development

Mapping resource, transmission and constraints (2/3)

Example of a Kenyan sensitivity analysis prepared by The Biodiversity Consultancy (TBC) and BirdLife International (The Biodiversity Consultancy, BirdLife International, Nature Kenya and The Peregrine Fund 2019).

a) Economically-viable wind areas for Kenya (from IRENA multi-criteria analysis) and existing and planned transmission lines.
b) Bird and bat sensitivity map for wind energy infrastructure.
c) Economically-viable wind areas and existing and planned energy transmission infrastructure overlaid with the sensitivity map.
d) Sensitivity within viable wind areas

Bird and bat sensitivity

- Low (10 - 376)
- Medium (377 - 430)
- High (431 - 801)
- Very High (802 - 3366)
- Outstanding (3367 - 5832)

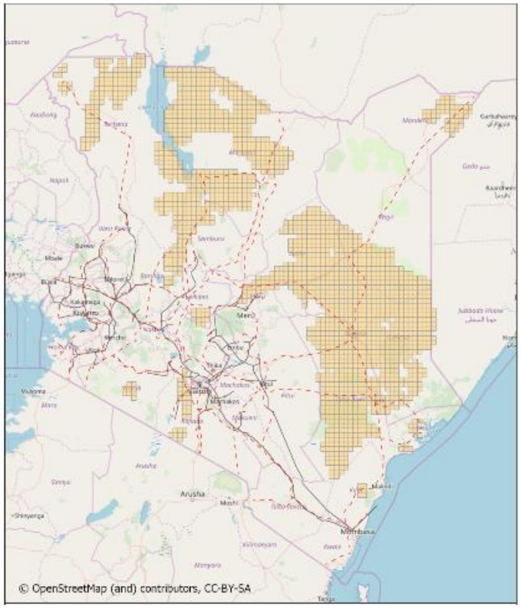
Wind farm locations

- ▲ ERC
- ◊ LCPDP
- + Others
- ★ WindForce

Bird and bat sensitivity

- Wind area
- KETRACO Proposed transmission lines
- Existing transmission lines

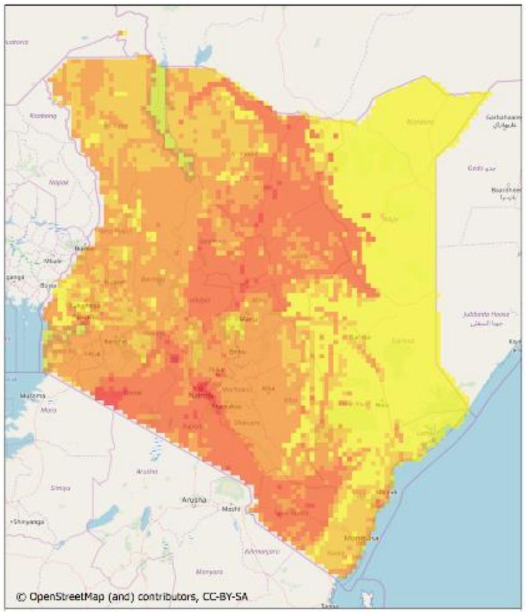
a)



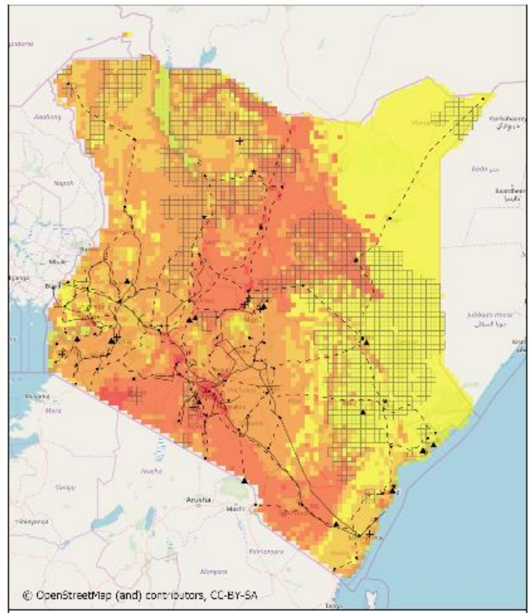
Wildlife sensitivity map development

Mapping resource, transmission and constraints (3/3)

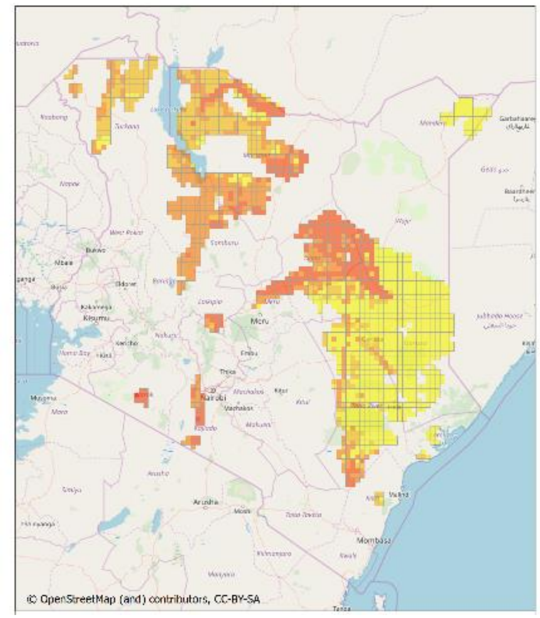
(b)



(c)



(d)



Wildlife sensitivity map development

Geographic information systems (GIS) and map presentation (1/2)

The development of a wildlife sensitivity map is an exercise in cartography that will require the use of a geographic information system (GIS). GIS is used to manipulate, analyse and present spatial data. A range of GIS software is available including both commercial and open source applications, but all require a basic understanding of geographic coordinate systems, map types, map projections and map design and symbology. In general, some training in GIS is therefore essential, especially for sophisticated mapping exercises such as wildlife sensitivity mapping.

Choosing between open source and commercial GIS software is largely an issue of cost and personal preference. In general, commercial applications will be more user-friendly, with more features and better technical support. Open source GIS software is free (but still requires the expertise of trained GIS specialists) and arguably affords a greater level of freedom and customization.

Typically, spatial features are mapped as points, lines or polygons, whilst there are two broad methods used to store spatial data in a GIS: raster (an array of cells holding a single value characterizing all of that cell's area) or vector (a series of points, lines and polygons with each element having unique identifiers that link to geographic elements of the attribute data).

Whilst GIS platforms are needed to create wildlife sensitivity maps, they are not necessarily ideal for sharing and disseminating map outputs. Although GIS file formats, such as shapefiles, can be shared directly, they typically require some degree of expertise to manipulate and view. It is therefore worth considering how best to present the mapping results. Most simply, maps can be output as image file formats, such as JPEG or PNG, or a document file format, such as PDF, and shared directly or added to reports or presentations. Spatial layers can also be converted to the KML file format used to display geographic data in an Earth browser such as Google Earth. The most advanced treatment is to present the map through a web-platform. This

Wildlife sensitivity map development

Geographic information systems (GIS) and map presentation (2/2)

approach is by far the most dynamic, enabling a more interactive and immersive experience. However, it should be noted that dynamic web platforms displaying interactive maps require considerable technical ability to create and maintain. This is therefore a costly and complex option.

Examples of wildlife sensitivity mapping

- Review of existing wildlife sensitivity mapping approaches
- Wildlife sensitivity mapping examples

Examples of wildlife sensitivity mapping

Review of existing wildlife sensitivity mapping approaches (1/6)

Prior to the preparation of the manual, a comprehensive review was undertaken to identify, describe and evaluate existing wildlife sensitivity mapping approaches developed to inform the deployment of renewable energy. In addition to academic literature identified using Web of Science (WoS), the review surveyed "grey literature" relating to work commissioned by government agencies, NGOs and environmental consultancies. Much of this information was identified through direct correspondence with a network of leading specialists.

Review findings

The review identified and assessed twenty-four wildlife sensitivity mapping exercises. It is important to note that not all the approaches are fully developed sensitivity maps intended to guide the deployment of renewable energy. Many are instead academic exercises that aim to demonstrate the feasibility of such approaches. Far fewer are planning tools developed in consort with national agencies or other end-user groups for applied use.

The overwhelming majority (24 out of 25) of these approaches have been developed for wind energy. Wind has emerged as the leading renewable technology with significant capacity already established in a number of countries. Wind is also a spatially abundant resource and there is consequently considerable scope for using mapping techniques to identify sites that have both suitable wind resource and low wildlife conflict. Wind energy is associated with a number of highly specific impacts, including collision, barrier effects, disturbance and displacement. Extensive research has now been conducted on these threats—how they operate, which species groups are most affected and under what circumstances. Consequently, there is perhaps greater scope with wind energy for devising methods that translate biodiversity data into a credible measure of sensitivity.

Nearly all of the approaches identified through the review focus on birds. Just nine cover bats or other mammals. Partly this

Examples of wildlife sensitivity mapping

Review of existing wildlife sensitivity mapping approaches (2/6)

reflects the nature of threats posed by wind energy, where birds have been identified as a major impact group. However, it also reflects the comparably greater information that exists on birds compared to other taxa, both in terms of the scientific understanding of the risks, but also the greater abundance of underlying data on their distribution and abundance. There is also some evidence that whilst at-risk bird communities are intermittently distributed, and thus can be mapped and avoided, vulnerable bats occur more uniformly and may therefore be less appropriate subjects for sensitivity mapping.

The review demonstrates that there is not a single, universal approach to sensitivity mapping. Instead, each approach is a custom-made response to specific regional circumstances. Approaches vary depending on the species and habitats of concern, the extent, type and quality of underlying data, and the planning framework into which the approach is intended to fit. None of the approaches offers a comprehensive solution—all focus on a limited number of renewable technologies and a subset of vulnerable species and habitats. It is likely that any attempt to develop a comprehensive wildlife sensitivity map, or series of maps, for all renewable technologies and all affected wildlife groups, either at a national or EU-wide scale, would require adopting attributes from a number of existing approaches combined with further innovation or novel techniques.

Most approaches are cautious in stating how the maps should be interpreted, often stressing that areas of apparent high sensitivity should not necessarily be construed as ‘no go areas’ and that map predictions do not negate the need for more substantive site-level assessment.

Although some maps have been developed in collaboration with government agencies, none of the approaches are a mandatory component of renewable energy development in the respective country or region. Most approaches are designed to be open-access resources with limited data available on how they are being used. In addition, developers, financial

Examples of wildlife sensitivity mapping

Review of existing wildlife sensitivity mapping approaches (3/6)

institutions and planning authorities are reluctant to divulge information on precisely how siting decisions are arrived at, and it is consequently difficult to estimate the frequency with which tools have been utilised. The majority of map authors interviewed in the course of the review acknowledge that the degree of uptake for their tools is likely to be low. Possible reasons cited include:

- Lack of legal requirement to conduct strategic landscape-level planning.
- Incompatibility with planning and consenting procedures.
- Lack of standardised approaches.
- Lack of approaches covering all species and habitats of potential concern.
- Concerns that wildlife sensitivity mapping approaches are imprecise.

Gaps

Clearly further consideration of taxonomic groups such as bats and marine mammals is needed. In many ways, the lack of robust sensitivity mapping approaches for these taxa reflect gaps and deficiencies in knowledge generally about their distribution and abundance, as well as the need for more systematic and widespread monitoring of these groups. There are also significant gaps in our understanding of the wildlife impacts associated with certain renewable energy technologies. More research is, for instance, needed on the impacts of solar energy. The extent to which problems such as "lake effect", whereby waterbirds collide with solar arrays that they mistake for water bodies, is still largely unknown. A better understanding of the threats will result in more appropriate sensitivity mapping solutions.

Very few wildlife sensitivity maps integrate other spatial factors influencing site appropriateness, such as resource potential,

Examples of wildlife sensitivity mapping

Review of existing wildlife sensitivity mapping approaches (4/6)

technical feasibility, topography, grid connectivity and other social, political and environmental constraints. The more that these determining factors can be evaluated simultaneously, the more likely that optimal planning decisions will be made.

Costs

The approaches vary considerably in their purpose and scope and consequently in the costs involved in their production. Factors that influence cost include:

Data sources. Mapping approaches that utilise existing datasets are less costly than exercises that require new surveys and studies to be conducted.

Level of detail. The more comprehensive the data collation, and the finer the spatial resolution, the more costly the mapping exercise. Whilst it is clearly desirable to have maps that are as detailed and data-rich as possible, it is worth remembering that even basic mapping exercises can be enormously valuable in informing and improving early planning decisions.

Taxonomic scope. Broader taxonomic focus is likely to be associated with higher costs. Taxonomic groups whose distribution and abundance is poorly known are more likely to require addition data collection and consequently will incur greater costs. Certain survey methods, such as satellite and GPS telemetry, are more costly.

Sectoral scope. Different renewable energy sectors impact wildlife in different ways. For instance, there are considerable differences in the ways in which on- and offshore wind energy affect ecological communities. A greater level of

Examples of wildlife sensitivity mapping

Review of existing wildlife sensitivity mapping approaches (5/6)

complexity is needed to address multiple renewable energy sectors through a single mapping tool and this may have cost implications.

Analytical tools. All sensitivity mapping approaches require some level of GIS-based analysis. Whilst some software packages are free, open-source products, others can be expensive. Irrespective of the software, GIS analysis requires specialists with considerable training and expertise.

Additional spatial mapping. Wildlife sensitivity maps can be augmented with additional information on renewable resource availability and other spatial considerations. Whilst doing so has clear advantages in terms of planning, it can add to overall cost.

Map format. Sensitivity maps can be disseminated in a number of different formats, for instance as high-resolution images, as a geodatabase containing spatial GIS layers, or as an online web-tool. What format is chosen will have significant cost implications. A web-based platform may offer the greatest level of interactivity and reach the widest audience, however it is a more costly endeavour, requiring the work of specialist web developers. It is also worth noting that web-platforms require ongoing maintenance costs.

Update cycle. Ecological communities are dynamic, whilst datasets grow and expand. Consequently, maps designed to permit regular update are likely to be more robust that one-off mapping exercises. The frequency and scale of update will, however, have cost implications.

Examples of wildlife sensitivity mapping

Review of existing wildlife sensitivity mapping approaches (6/6)

It is important to note that the costs associated with even the most complex and data-rich sensitivity mapping approaches are likely to be modest in comparison to the technical development costs of renewable energy and the overall value of national renewable energy sectors. The costs associated with proactively identifying and minimising wildlife impacts prior to development are likely to be much lower that the costs associated with retrospectively addressing poor siting decisions.

Examples of wildlife sensitivity mapping

Wildlife sensitivity mapping examples (1/4)

The following section summaries 25 wildlife sensitivity mapping exercises from around the world. These were chosen following an exhaustive literature review and represent the breath and diversity of approaches developed to date. Each example includes a description of the datasets and analytical approaches used, as well as an evaluation of uptake, effectiveness and adaptability. To ensure that the technical descriptions provided are accurate, the authors of each approach were consulted. The evaluation of each approach is based on their feedback and on the judgement of a team of specialists with a background in wildlife sensitivity mapping.

The first eight of these examples are particularly instructive. They include examples from a geographically diverse array of EU Member States. Most were developed in collaboration with end-user groups, cover a significant number of vulnerable species and assign an explicit sensitivity value. Some of these tools are widely used by planning authorities and/or other stakeholders within their country or region.

Key examples

UK sensitivity mapping exercises conducted by the RSPB

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland

Wind farm sensitivity map for birds and bats in Flanders (Belgium)

BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa

Examples of wildlife sensitivity mapping

Wildlife sensitivity mapping examples (2/4)

- Wind farm Sensitivity Index for seabirds in the German North Sea
- Soaring bird sensitivity map for wind energy development in Thrace (Greece)
- Bulgarian wind farm sensitivity mapping
- Wind farm sensitivity mapping in France: A review of several regional approaches

Additional examples

- SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters
- Regional locational guidance for wave and tidal energy in the Shetland Islands (UK)
- Israel national wind farm sensitivity map, based on distributions of birds and bats
- Lithuanian sensitivity map for birds and bats in relation to onshore wind
- The Netherlands national wind farm sensitivity map
- Smart Wind Chart evaluation tool for offshore wind in the Mediterranean and Black Seas

Examples of wildlife sensitivity mapping

Wildlife sensitivity mapping examples (3/4)

- Avian wind farm sensitivity map for South Africa
- Wind energy sensitivity mapping in Germany (WWF Germany)
- Seabird sensitivity mapping for offshore marine renewable energy developments in Ireland
- Site Wind Right (Low-impact Wind Mapping Tool)
- BFN EE100 - Nature-compatible energy supply from 100% renewable technologies by 2050
- Greek national wind farm sensitivity map for birds
- Slovenian national wind farm sensitivity map for birds
- A spatial conservation prioritisation approach for protecting marine birds given proposed offshore wind energy development (USA)
- American Bird Conservancy Wind Risk Assessment Map
- Mapping risk for a bat species in the Molise region, Italy

Examples of wildlife sensitivity mapping

Wildlife sensitivity mapping examples (4/4)

Assessment of wind farm impacts on large carnivores in Croatia

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (1/10)

RSPB

Summary

The RSPB's 2050 Energy Vision developed a series of sensitivity maps for a range of operational and anticipated renewable energy technologies. The project presents three 'Low Ecological Risk' energy scenarios that explore whether, and how, an 80% emissions reduction target could be met by 2050 using a combination of demand reduction and renewable technologies in harmony with nature.

The technical development of the maps pulled together a wide range of data sources and utilised a set of equations to display sensitivity of birds and marine megafauna to renewable energies at the 1km^2 scale. The sensitivity mapping included both site-based and species-based considerations for bioenergy crops, solar farms, onshore and offshore wind, wave and tidal stream energies.

The maps developed through the RSPB 2050 Energy Vision project are a leading example of wildlife sensitivity mapping taking into account realistic constraints on energy development. The techniques employed could be readily scaled-up and applied to other regions in the EU where analogous data are available.

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (2/10)

Geographic scope	National
Renewable energy sector	Onshore wind, Offshore wind, Solar, Bioenergy, Wave, Tidal
Taxonomic focus	Birds of prey, Seabirds, Waders, Anseriformes (ducks, geese, swans), Phasianidae (pheasants) - Black Grouse, Passerines, Chough, Nightjar; Stone Curlew, Corncrake, Cetacea (whales, dolphins, porpoises), Pinniped (seals) , Distribution of nursery/spawning grounds for selected fish species; sightings of basking sharks
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public / partially restricted
Format	Static map and GIS shapefile
Data sources	Species range maps, Species records, Habitat maps, Conservation sites, Topography, Resource maps, Nursery and spawning grounds
Factors contributing to the calculation of sensitivity	Global conservation status (e.g. IUCN Red List), National conservation status, Habitat Sensitivity, Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.)
Intended data update cycle	Not planned
Use in planning process	Not mandatory
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (3/10)

Data

The maps make use of a wide range of designated site types and key habitats, utilising pre-existing, large-scale datasets. For the analysis, the combined species list first developed for wildlife sensitivity mapping in Scotland and England (Bright *et al.* 2008; 2009) was expanded to include data from Wales and Northern Ireland. Some species were not included in the sensitivity map because of problems with data access, data availability or rapidly expanding distributions. The offshore maps not only used data for seabirds, but also included nursery and spawning grounds for fish, basking shark sightings data and important areas for marine mammals.

Data on physical and policy constraints on the deployment of renewable energy were included. For all onshore technologies, the majority of the constraints were based on the SQW Energy (2010) methods for commercial scale onshore wind. The constraints for offshore technologies were obtained from The Crown Estate's GIS database and selected under the same criteria as for onshore technologies.

Data representing renewable energy resource were included, based on methods by SQW Energy (2010). No minimum level of irradiance or energy output had been determined for commercially viable solar energy in the UK so solar data were based on the European Commission's Institute for Energy and Transport solar radiation map. The opportunity maps for offshore wind (fixed and floating turbines), wave and tidal stream energy were obtained from The Crown Estate (2012); these maps varied in their degree of accuracy and were only indicative of future resource potential at a general level.

Analytical approach

- Three levels of ecological risks (High, Medium and Low) were assigned to all major renewable energy technologies (see table).
- The Protected Area network in the UK was used as a starting point for developing the sensitivity maps and a decision tree was used to determine the mapping approach for each technology, the first nodes representing the mapping of Protected Areas.
- High sensitivity was assigned to areas afforded protection

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (4/10)

through international and national legislation and medium sensitivity for any other designations. Buffers were not added around protected areas.

High risk technologies	Medium risk technologies	Low risk technologies
New large-scale hydropower	Onshore wind	Solar PV in the built environment
Tidal range power (shore-to-shore barrages and lagoons)	Solar farms	Small-scale wind
	Bioenergy technologies	Geothermal electricity
	Offshore wind (fixed-base and floating turbines)	Small-scale hydropower
	Wave power	Low carbon heat technologies
	Tidal stream	

- Data on the distributions of species sensitive to particular renewable technologies were included to supplement the protected areas layer. Areas supporting species without distribution data of sufficient quality were assigned low/unknown sensitivity. This recognises that it would be inappropriate to assume the absence of species (such as some marine birds) with the limited understanding of their movement patterns at the time.
- Certain habitats were identified as sensitive to different technologies and allocated medium sensitivity, including ancient semi-natural woodland, deep peat, organic and peat soils, and semi-natural grasslands.

Onshore wind

- The methods for the onshore wind sensitivity mapping repeated those for earlier avian sensitivity maps for England and Scotland (Bright *et al*. 2008, 2009).
- Species sensitive to onshore wind were identified through a literature review focussing on species with potential collision risk and those sensitive to disturbance and habitat change. Additionally, sensitive species included those undergoing rapid population declines and having localised populations.
- 26 bird species were identified as being sensitive to onshore wind development. Older data was assigned medium sensitivity to recognise that it may not reflect the more recent changes in species distributions.

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (5/10)

Offshore wind, wave and tidal stream energy

- 22 seabird species included in the offshore sensitivity mapping were UK breeding species listed as potentially sensitive by Furness *et al.* (2012) and Furness *et al.* (2013), for which colony counts were undertaken as part of the Seabird 2000 census. Species sensitivity factors from these papers were applied as weightings for each species in the sensitivity scoring.
- Distribution data was included for wintering seabirds (Bradbury *et al.* 2014) and marine megafauna (Batey and Edwards 2014) supplemented by data from the Areas of Additional Pelagic Ecological Importance (APEI).
- Supplementary data from SeaMaST (Seabird Mapping and Sensitivity Tool) was included to account for the distribution of overwintering seabirds and those that do not breed in the UK.
- Seabird colonies were buffered by the mean maximum foraging distance for the resident species (Thaxter *et al.* 2012). Without detailed tracking data at the time, seabirds were assumed present uniformly across the buffer areas.
- As with the onshore maps, layers were categorised into high sensitivity, medium sensitivity and low/unknown sensitivity areas using Jenks natural breaks optimisation.
- The maximum sensitivity category for each species relating to collision and disturbance/displacement was chosen in each grid square of the sensitivity map.

Bioenergy crops and solar farms

- For both these technologies, the sensitivity mapping focused on taxa, which would be negatively affected by habitat and land use change. These included those specialist species that would be sensitive to loss of seed-rich habitats, such as grasslands and uplands.
- Buffers were applied to known breeding and aggregation locations for 11 species based on disturbance and displacement potential. The extent of these buffers was determined following literature review.
- An additional 18 species of arable birds, farmland waders and upland waders were assessed at the assemblage-level based on data from the BTO Bird Atlas. Each species was given a score of 1/number of 10 km^2 squares in the UK in which it was present. Scores in the top quartile (25%) were

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (6/10)

classified as medium sensitivity.

- The final sensitivity maps for each technology were produced from a composite map of the species and assemblage distribution layers and the protected areas layer. The highest sensitivity value was selected for each 1km^2 cell. Equations for the calculation of sensitivity values are available in the full report.

Additional features

After developing sensitivity maps for each technology, the DECC 2050 Pathways Calculator1 was used to develop three low ecological risk (LER) 2050 energy scenarios for the UK (Mixed Renewables, High Marine Renewables and High Onshore Renewables), allowing for environmentally sustainable, secure and affordable energy.

Physical and policy constraints were also considered to produce a realistic output to the analysis. Physical constraints were deemed to be activities and infrastructure that precluded development and therefore should be treated as fixed exclusion zones. Policy constraints were selected as areas where development would be unlikely under current or proposed legislation and/or practice. For offshore technologies, physical constraints were identified as areas where there is an existing infrastructure or where alternative seabed use is in place.

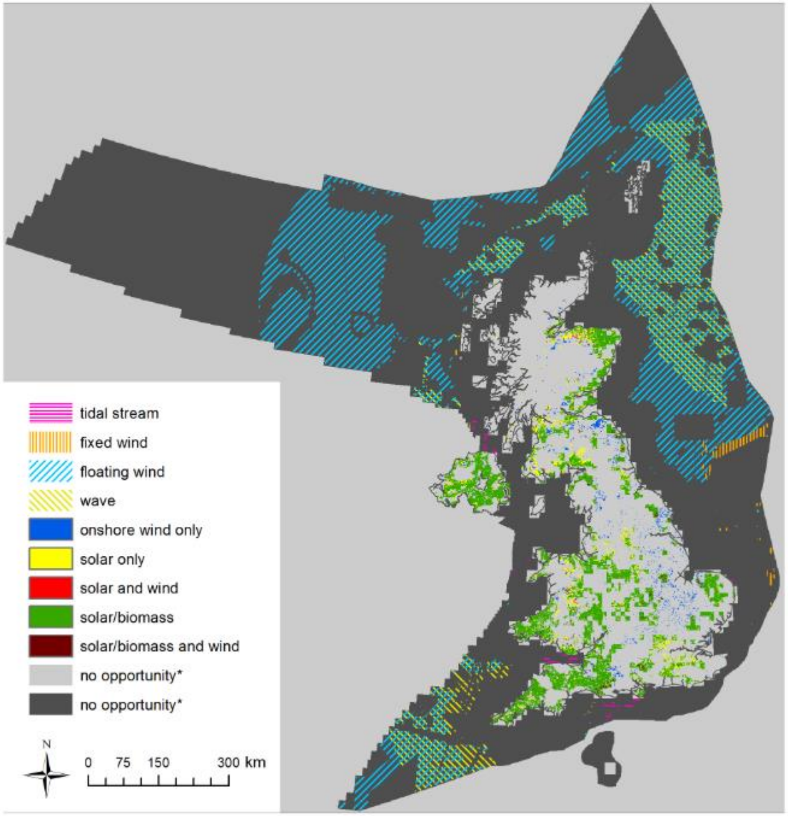
The '2050 energy vision' also presented policy recommendations. These included an outline of ten steps necessary to meet the UK's climate targets in harmony with nature.

Uptake

The results of lower sensitivity energy generation opportunity (in GW/TWh terms) that the RSPB calculated using the maps have informed energy scenario modelling by the National Grid. The maps were designed to identify areas at a broad scale that might be suitable for certain technologies. Many developers are aware of the work, but do not actively take it into account in their decision-making as other factors and drivers are considered of more importance.

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (7/10)



Opportunity mapping for tidal stream, fixed wind, floating wind, wave, onshore wind, solar and bioenergy crops, showing areas of opportunity with low/unknown ecological sensitivity. *Areas of no opportunity (Light grey on land; dark grey at sea) show areas excluded due to lack of resource opportunity, presence of physical or policy constraints and/or high or medium ecological sensitivity.

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (8/10)

Effectiveness
The maps were intended to indicate the maximum areas available for deployment of each technology without conflicting with nature conservation interests, and do not account for the actual likelihood of a technology being deployed.

Not all areas identified as sensitive will necessarily represent exclusion zones for renewable technologies after ground truthing, but the maps can help to identify target species for detailed assessment of population sizes and potential impacts and to identify potential mitigation options.

In general, high confidence can be attributed to the anthropogenic physical and political layers. In addition, the use of presence/absence data does not allow the discrimination of relative importance for specific areas and identification of how they are used; it is therefore difficult to determine how well sensitivity is represented. The quality of the underlying ecological data is highly variable due to the age, scale and accuracy of the data.

Despite this, the mapping process has indicated which missing or limited datasets would provide more clarity to the outputs, and should be created or updated. For example, areas of low ecological sensitivity are not distinguished from areas of unknown ecological sensitivity in this mapping process, owing to gaps, uncertainty and resolution of underlying datasets. These areas are therefore represented in the same colour on the maps, meaning that precaution is needed when interpreting the sensitivity of these areas.

The species assemblage approach used for bioenergy crops and solar farms has led to a relatively high percentage of land being classified as medium sensitivity. In large part, this is due to an insufficient knowledge of the potential ecological impacts of energy crop cultivation and of solar farms.

Information gaps exist with respect to the nature of potential impacts of renewable technologies, the identity of sensitive species and the quality of distribution data, particularly for species at sea. Whilst the body of data has grown considerably in recent years (not least through offshore wind farm

Examples of wildlife sensitivity mapping

RSPB's 2050 Energy Vision sensitivity mapping for the UK (9/10)

development), data for pelagic areas remain limited and caution must be applied when inferring sensitivity far from the coast. Data are also limited for seabirds at breeding colonies; the last national seabird census took place between 1998 and 2002, and so may not reflect current abundances.

Furthermore, the network of protected sites at sea is much less comprehensive than that on land. This was partly accounted for in the sensitivity maps by including proposed protected areas and increasing the sensitivity ratings of other sites (e.g. Important Bird and Biodiversity Areas). However, until there is a robust network of marine protected sites, the status/importance of areas of sea with low/unknown sensitivity must be approached with caution.

Adaptability

The tool is versatile, allowing many different technologies to be examined in relation to each other. This is the leading example of how to develop maps, for a suite of renewable energy sources, that allow decision-makers to plan renewable energy development in a strategic, nationwide manner. Its practical utility is enhanced through the inclusion of comprehensive physical and policy constraints.

This type of exercise could be scaled up both in terms of geographic extent and the number of technologies considered. The maps could also be expanded to include additional constraints, such as grid connectivity, and further ecological risks, such as those associated with cumulative impacts.

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Examples of wildlife sensitivity mapping

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The RSPB's 2050 energy vision. Meeting the UK's climate targets in harmony with nature.

URL Onshore wind opportunity showing sensitivity and constraints

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (1/7)

Birdwatch Ireland

Summary
BirdWatch Ireland's sensitivity mapping tool for wind energy developments in the Republic of Ireland enables the user to identify areas of high avian sensitivity with respect to impacts of onshore wind energy development. It is intended for use in early stage screening, planning or assessment only.

Users have access to extensive spatial datasets relating to the species most vulnerable to wind energy development in terrestrial areas. Species were selected for inclusion based on a clearly defined scoring system. Selection criteria are based on a combination of vulnerability and conservation status factors.

One of the limitations of the tool is the exclusion of some key species that scored highly sensitive, but could not be included because of data deficiency or the desire not to publicise sensitive information on the locations of some rare species.

The tool was widely promoted during the development stages, and the map layers have been integrated within the mapping systems used by planning authorities.

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (2/7)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Waders, Anseriformes (ducks, geese, swans), Passerines
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Public
Format	Mapping interface, GIS shapefile
Data sources	Species records
Factors contributing to the calculation of sensitivity	Proportion of global population, Global conservation status (e.g. IUCN Red List), National conservation status, EU conservation status (Nature directives), Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.)
Intended data update cycle	Dependent on funding and new data
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (3/7)

Data
The tool is based on data layers generated from a variety of surveys (listed below):

Annual

- Corncrake monitoring.
- Irish Wetland Bird Survey (Boland & Crowe 2012): Annual national surveys of non-breeding wintering waterbirds across Ireland, since 1994/95, and including associated species-specific surveys undertaken on a scheduled basis (e.g. swans every five years).
- Raptor Conservation Project of BirdWatch Ireland.
- Breeding Red-throated Diver surveys (National Parks and Wildlife Service).
- Grey Partridge monitoring, coordinated by the National Parks and Wildlife Service (NPWS) and the Irish Grey Partridge Conservation Trust (IGPCT) (unpublished data).

Regular

- National Hen Harrier surveys conducted every 4-5 years in conjunction with the National Parks and Wildlife Service, the most recent of which was conducted in 2010 (Ruddock *et al*. 2011).
- Seabird colony surveys every 15 years, last was Seabird 2000 survey (1998 – 2002) (Mitchell *et al*. 2004).

Occasional

- All-Ireland Tern Survey (1995).
- All-Ireland Chough survey (2002-2003).
- Upland Bird Surveys 2003 and 2004 (Cummins *et al*. 2004; Cummins *et al*. 2003).
- Red Grouse survey 2006 – 2008 (Cummins *et al*. 2010).
- Twite breeding ecology (McLoughlin 2009, PhD thesis).
- Resurvey of breeding wader populations of machair and associated wet grasslands in north-west Ireland, as commissioned by the National Parks and Wildlife Service (Suddaby *et al*. 2010).
- Common Scoter breeding survey 2012, commissioned by the National Parks and Wildlife Service (Hunt *et al*. 2013).
- All-Ireland Breeding Wader Survey 2013.
- Bird Atlas 2007-2011 (Balmer *et al*. 2013).

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (4/7)

Analytical approach

1. Identification of species appropriate for the model through consultation, eliminating offshore seabirds and other species not relevant through a decision-tree matrix.
2. The calculation of the Species Sensitivity Score (SSS) integrated a broad variety of factors, namely:
   - Factors relating to conservation status and population ecology, including national conservation status, proportion of the population in Ireland and adult survival rate.
   - Vulnerability factors relating to flight, such as size, soaring flight style, aerial foraging, ranging behaviour, flocking behaviour, nocturnal flight and aerial display.
   - Vulnerability factors relating to habitat, such as range, site fidelity, availability of preferred habitat, habitat preference and sensitivity to disturbance displacement.
3. Each factor was given a score, between 0 and 4, with higher scores reflecting higher sensitivity (following external consultation with species experts).
4. The Species Sensitivity Score (SSS) was then calculated in the following steps:
   - The final vulnerability score (o) was calculated as the sum of the average scores within each of the two vulnerability groups above (species and habitat).
   - The final population score (v) was calculated as the maximum score of the three population categories status plus the annual adult survival rate.
   - SSS = Final vulnerability score (o) x Final population score (v)
5. Application of sensitivity scores to spatial data (Low, Medium, High and Highest), and generation of a composite layer. The final spatial layer was created using ArcMap 10.0 (Esri Inc., Redlands, California). A buffer zone of sensitivity was first generated for each species layer. The buffered areas were each clipped using a standard 1-km grid based on the Irish National Grid projection. This operation standardised each species' distribution to that 1-km grid, and facilitated the summation of the SSS across each of the 1-km squares resulting in a single total for each cell.

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (5/7)

Additional features
An online web tool provides an effective means for end-users to access and use the map. The map is hosted by the National Biodiversity Data Centre, which reduces the financial burden for BirdWatch Ireland with regard continued maintenance and upgrade. This also enables viewing of the species sensitivity layer together with other biodiversity layers housed within the National Biodiversity Data Centre.

Uptake
Several workshops were delivered to stakeholders to promote the tool. BirdWatch Ireland continue to encourage the tools use with appropriate stakeholders.

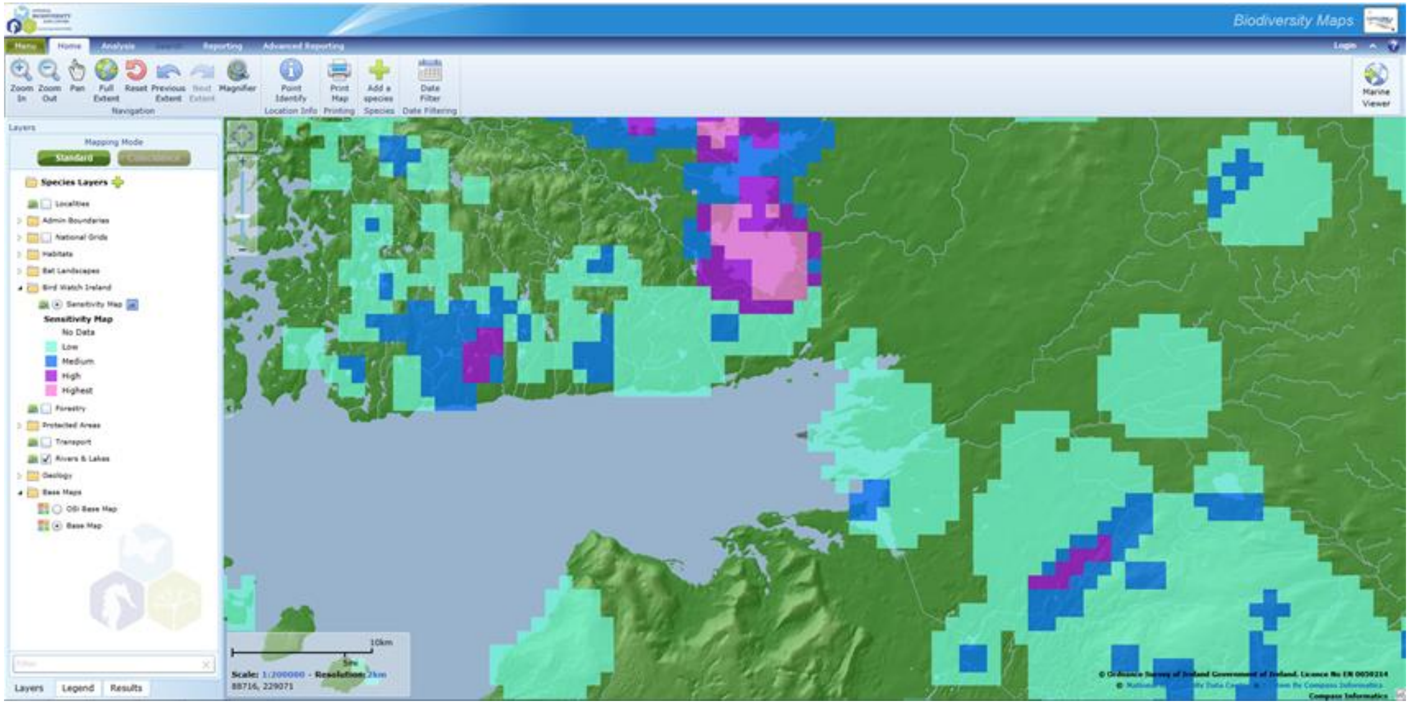
Effectiveness
The effectiveness of the tool is highly dependent on the quality of the underlying data, and unfortunately, there were many key species layers that were not included due to data deficiency or species sensitivity, some of which had relatively high sensitivity (e.g. Golden Eagle *Aquila chrysaetos*). Assessments using the tool should only form part of a siting decision and do not replace the need for adequate Environmental Impact Assessment. The tool is expected to be more effective in the future when these data updates can be incorporated.

Adaptability
The methods are proven and could be readily extended to additional areas, and/or to other sectors. Similar methods have since been used by BirdWatch Ireland in the development of both forestry and marine sensitivity maps, both of which are at trial stages. The tool could also be expanded to additional avian groups and to other taxa where sufficient data are available. This methodology for calculation of sensitivity scores could be applied to the risks associated with other renewable technologies.

The tool adopts closely many aspects of other tools that have been developed to date (e.g. Garthe and Hüppop 2004), which adds strength to the methodology, especially when promoting the tool among developers and other stakeholders.

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (6/7)



Screenshot of the mapping tool. Clicking on a single 1 km square returns a list of species present, their individual Species Sensitivity Score and the aggregate sensitivity score for the polygon.

Examples of wildlife sensitivity mapping

Bird sensitivity mapping for onshore wind energy and associated infrastructure in the Republic of Ireland (7/7)

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Examples of wildlife sensitivity mapping

Wind farm sensitivity map for birds and bats in Flanders (Belgium) (1/7)

Research Institute for Nature and Forest (INBO)

Summary
The wind farm sensitivity map for birds and bats in Flanders is one of the few examples of a multi-taxa sensitivity map and provides an insight into how dissimilar groups can be accommodated within a single tool. Although aspects of the map are distinctive to Flanders, the principles could be readily applied elsewhere. The fact that it has routinely used within the development process suggests that many features of this tool should be investigated to see how they might be applied elsewhere within the EU.

The map classifies the region into four categories of high, medium and possible risk, as well as low risk/no data. It includes a GIS based vulnerability map for birds, which is made up from several component maps including information on important bird areas and migration routes. This map can be consulted in detail within a web-based application alongside other important spatial layers (like protected nature reserves, Natura 2000 areas, etc.).

The map also includes information on bats; however, it should be noted that both the level of data available on bats, and the level of knowledge on how they are impacted by turbines, is much lower than for birds. Consequently, greater caution should be exercised when interpreting the sensitivity forecasts for bats.

Background information and guidance (in Dutch)

Examples of wildlife sensitivity mapping

Wind farm sensitivity map for birds and bats in Flanders (Belgium) (2/7)

Geographic scope	Regional
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Seabirds, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Passerines, Bats
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Public
Format	Web-based mapping Interface, GIS Shapefile
Data sources	Species range maps, Species records, Habitat maps, Migration routes
Factors contributing to the calculation of sensitivity	Proportion of population in Flanders, Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.)
Intended data update cycle	2-5 years
Use in planning process	Map developed with a government agency
Percentage of siting decisions in which the tool is utilised	81-100%

Examples of wildlife sensitivity mapping

Wind farm sensitivity map for birds and bats in Flanders (Belgium) (3/7)

Data

Sources of data include the wintering waterfowl database, which holds data from more than 1,000 sites in Flanders from six-monthly winter counts and data from 400 field ornithologists, and the breeding bird database in Flanders (including data from http://www.waarnemingen.be), as well as local bird surveys and knowledge collected from bird working groups and http://www.trektellen.be. Bat sensitivity is derived from the extent of potential habitats, which is estimated from aerial photographs and a field inventory map of biological valuation and land cover.

Analytical approach

The criteria to determine the sensitivity score of areas/flight routes are diverse. For bats, sensitivity is based on predicted suitable habitat. For birds, these are based on the percentage of the total regional population (Flanders), absolute numbers, and/or values of buffer distances (e.g. possible disturbance). In total, nine thematic maps were compiled separately and then combined into one overall synthesis sensitivity map. The nine thematic maps were comprised of:

1. Foraging and resting areas for waterfowl (non-breeding)
2. Roosting areas (non-breeding)
3. Breeding colony locations
4. Breeding areas for endangered/ rare birds
5. Breeding areas for meadow birds
6. Breeding areas for farmland birds
7. Regular flight corridors for foraging
8. Regular flight corridors for roosting
9. Seasonal migration routes

Additional features

The tool is open access via an online web viewer. The accompanying user document is only available in Dutch but includes comprehensive lists of species included, as well as all component maps and bat detection methods.

Uptake

This tool is widely used to inform siting decisions early in the planning process. Spatial planning authorities, as well as project developers and consultancies consistently use the tool as a

Examples of wildlife sensitivity mapping

Wind farm sensitivity map for birds and bats in Flanders (Belgium) (4/7)

starting point for strategic planning, and for assessing the risks related to selected locations before more detailed site-level assessments take place. Local and regional authorities use the tool routinely as a benchmark against which to assess the quality of assessments undertaken by project developers and consultancies. The EIA competent body in Flanders, which is in charge of the quality assessment of SEA and EIA, considers the application of the tool as a standard requirement for onshore wind energy developments. Some thematic bird maps from this project are also used as part of data contributing towards a sensitivity map for the mitigation of power lines in Belgium.

Effectiveness

The tool provides an effective means of initial site assessment within a user-friendly web platform. The map shows a gradation of potential risk for significant impacts on bird populations. It can be used at a strategic level (local and regional spatial planning) for mapping possible wind farm locations where more study will be needed and provisional 'no-go areas'.

Although the map has its limitations (detailed information is not available for all areas), it is used as a starting point for environmental impact analysis at a project level.

The approach used to determine bat sensitivity is clearly less robust and should be used with greater caution.

In terms of the underlying data, there is a desire to include more comprehensively avian flight path information (both regular commuting flights and migratory routes) across the whole of Flanders. At present, the nature of data collation was opportunistic and not consistent across the whole of Flanders, and therefore more accurate data is desired for both birds and bats. Furthermore, INBO recognise that it is important to improve the data on bats, for instance, by including real presence data (hibernation sites, colony locations) and modelling distributions generated from observation data. The map would benefit from being dynamically linked to the underlying data sources, thus enabling a more regular and straightforward data update cycle.

Adaptability

The principles used for assigning sensitivity and the methods

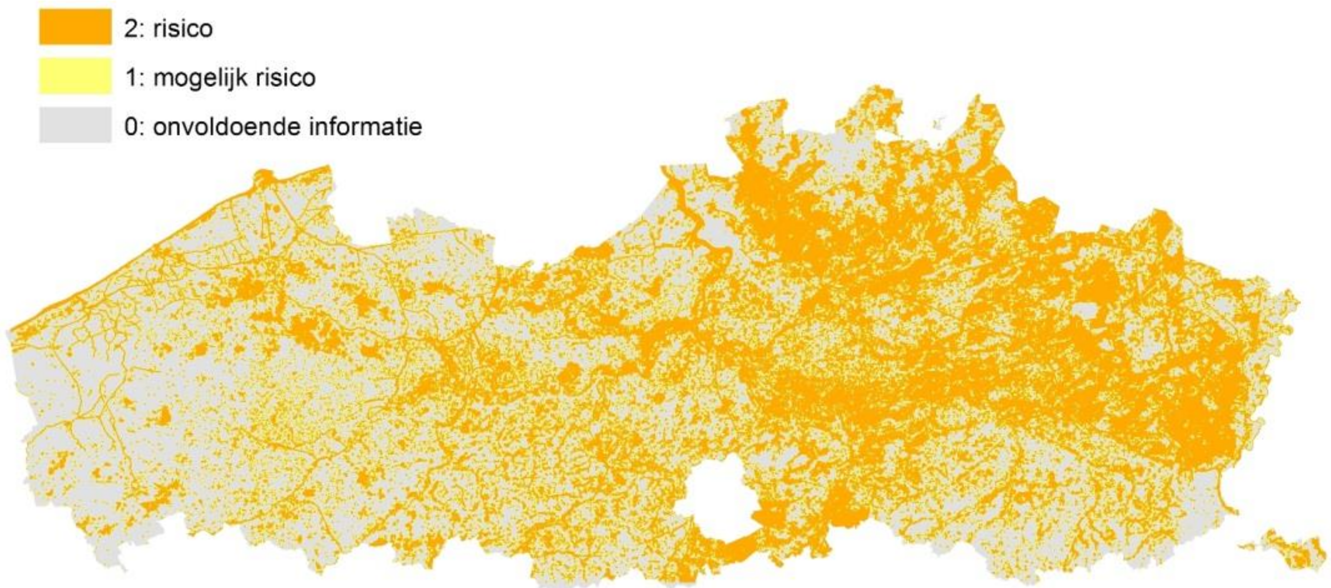
Examples of wildlife sensitivity mapping

Wind farm sensitivity map for birds and bats in Flanders (Belgium) (5/7)

used to produce an accessible interface can be adapted and transferred.

Examples of wildlife sensitivity mapping

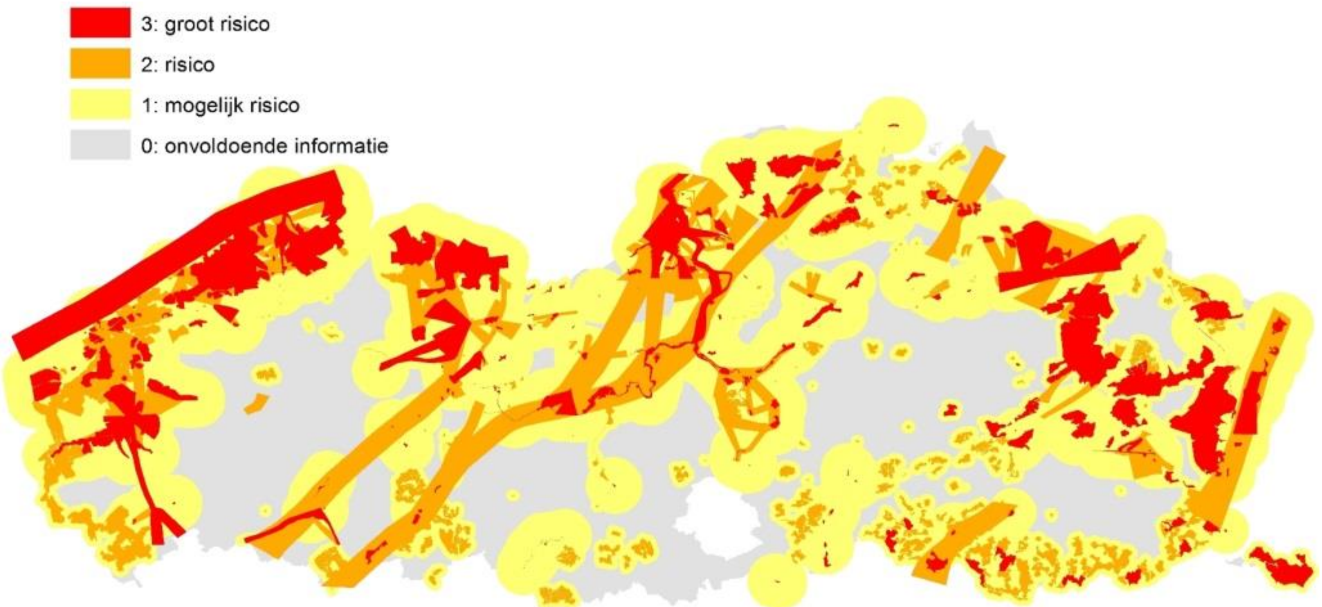
Wind farm sensitivity map for birds and bats in Flanders (Belgium) (6/7)



Synthesis map of bat sensitivity to wind turbines in Flanders.

Examples of wildlife sensitivity mapping

Wind farm sensitivity map for birds and bats in Flanders (Belgium) (7/7)



Synthesis map of bird sensitivity to wind turbines in Flanders.

Examples of wildlife sensitivity mapping

BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa (1/6)

URL

BirdLife International

Summary

Through BirdLife's Soaring Bird Sensitivity Mapping Tool, users have unrestricted access to extensive spatial datasets relating to soaring birds. Most significantly, a simple, explicit formula is used to assign sensitivity categories, thus allowing for an objective assessment and comparison of prospective locations on the basis of available data. The aim of the tool is to provide planning authorities, developers and other stakeholders with an authoritative, transparent and accurate assessment of the soaring bird sensitivity of a site in relation to wind farm or power line development. The tool focuses on the potential impact of terrestrial wind farms and associated infrastructure and is not intended to be used in the assessment of offshore developments.

The tool is one of the few regional tools covering multiple countries, and as such it provides useful insights into the use of existing biodiversity datasets over large geographical areas. The tool is also distinctive in that it does not display a single sensitivity layer, but calculates a sensitivity value only for user-defined search areas.

The tool is widely promoted with governments, developers and international financial institutions (IFIs) throughout the region covered and has informed numerous wind farm siting decisions.

Examples of wildlife sensitivity mapping

BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa (2/6)

Geographic scope	Multi-national
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of prey, Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons)
Intended users	Planning authorities, Government agencies, International financial institutions, Consultancies, Conservation NGOs, General public
Access	Public
Format	Web-based mapping Interface
Data sources	Conservation sites, Species records, Species range maps, Migration routes, Topography
Factors contributing to the calculation of sensitivity	Species collision susceptibility, Species population size (proportion of global population), Global conservation status
Intended data update cycle	Annually
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, IFIs, NGOs)
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa (3/6)

Data
The tool contains data on 89 species of soaring bird. The principal source of information is BirdLife's Important Bird and Biodiversity Areas (IBA) dataset (Donald *et al*. 2019, Waliczky *et al*. 2019).

Additional records were collated from a wide range of sources, including scientific journals, trip reports, environmental impact assessments and from Worldbirds (www.worldbirds.org), a global archive of bird observation records. It is these datasets that are used to calculate sensitivity values. Supplementary information, including soaring bird satellite tracking data and species' range maps, as well as spatial data on protected areas and relevant topography, are also included to provide additional context and insight.

Analytical approach
Unlike most WSMs, the tool does not depict sensitivity directly on the map. This is so as to avoid a simplistic interpretation. Instead, an assessment of sensitivity is only made for a defined search area. By doing this, the tool provides the best possible assessment, based on the available data of a selected location, without providing a potential misleading inference about the suitability of the wider landscape.

The tool calculates sensitivity using a simple algorithm based on the parameters listed below. The tool evaluates all the soaring bird records intersecting with the buffered search area, and sums the sensitivity scores for each species' population at the site to get an overall Sensitivity Index (SI), following the equations:

$$\mathrm{SI} = \mathrm{SSS1} + \mathrm{SSS2} + \mathrm{SSS3} \ldots\ldots \mathrm{SSSn}$$
$$\mathrm{SSS} = \mathrm{SSI} \times (\text{Site Population}/\text{Global Population})$$
$$\mathrm{SSI} = \mathrm{SVI} \times \mathrm{ERI}$$

SI Sensitivity Index of site
SSS Species' Sensitivity at Site
SSI Species' Sensitivity Index
SVI Species' Vulnerability Index
ERI Extinction Risk Index

Examples of wildlife sensitivity mapping

BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa (4/6)

Additional features

The tool is available in English, French and Arabic. Users have the option to download an assessment, combining maps, tabular data and instructions on interpretation and use, as a pdf document. This makes it easy for end-users to integrate the information within their internal planning decisions.

Uptake

The tool is well known amongst relevant stakeholders, especially International Financial Institutions (IFIs). Uptake continues to increase as the tool gains recognition. The tool is also promoted through the Convention on Migratory Species (CMS) Energy Task Force. At least one country (Egypt) has developed a national sensitivity map derived from the tool. Several IFIs, including the European Bank for Reconstruction and Development (EBRD) and the International Finance Corporation (IFC) have utilised the tool within their safeguarding and screening policies. Several major planning decisions have been influenced by the tool, however, it is likely that the vast majority of wind farm siting decisions in the region are made without reference to the tool.

Effectiveness

The tool provides a good summation of existing data on the avian group—soaring birds—that is most vulnerable to collision with onshore wind farms and power lines. The tool provides a standard approach across a very large area (with the potential to be global). In countries with weak nature legislation regarding the siting of wind energy infrastructure, or more limited national biodiversity data, the tool is likely to prove especially useful in supporting good siting decisions.

The effectiveness of the tool is highly dependent on the quality of the underlying data, the quality of which is highly variable across the region covered. Although the IBA dataset is one of the most robust global sources of biodiversity information, in some areas the data is quite old. Such data is still likely to be informative, especially at the early stages of a siting decision, but should be interpreted with care. The guidance associated with the tool clearly describes the data limitations and the need for cautious interpretation. Assessments are based on global conservation designations, which can be at odds with national and regional conservation priorities and nature legislation.

Examples of wildlife sensitivity mapping

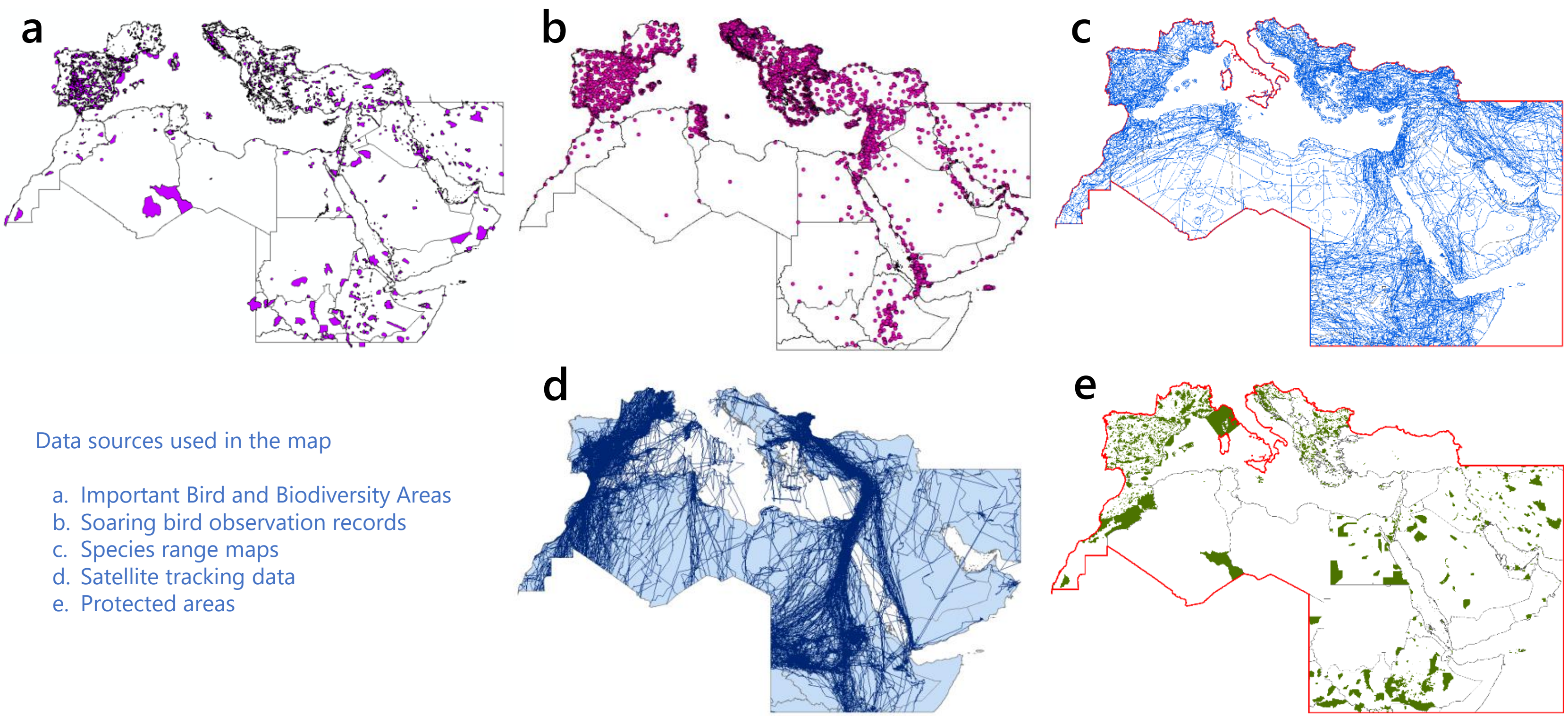
BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa (5/6)

Adaptability

The tool could be readily extended to additional geographical areas. Indeed, it has already been expanded once and further geographical expansion is underway. Although the tool only covers soaring birds, it could be expanded to additional avian groups, and perhaps other taxonomic groups. However, the methodology for assigning sensitivity is based on bird collision susceptibility. Therefore, it would require considerable modification to embrace additional threats associated with other renewable technologies and other species groups.

Examples of wildlife sensitivity mapping

BirdLife International Soaring Bird Sensitivity Mapping Tool – Southern Europe, Middle East and North Africa (6/6)



Data sources used in the map

a. Important Bird and Biodiversity Areas
b. Soaring bird observation records
c. Species range maps
d. Satellite tracking data
e. Protected areas

Examples of wildlife sensitivity mapping

Wind farm Sensitivity Index for seabirds in the German North Sea (1/4)

Research and Technology Centre (FTZ), University of Kiel

Summary

A wind farm sensitivity index (WSI) developed for seabirds as part of a study aimed at quantifying the impacts of offshore windfarm development on seabirds. The study was focussed and applied to the Exclusive Economic Zone and the national waters of Germany in the North Sea. Although a piece of academic research, and not planning tool per se, the seabird sensitivity index it describes has had significant influence on the subsequent development of offshore sensitivity mapping tools.

Nine factors were used to score species sensitivity. The resulting Species Sensitivity Indices (SSIs) for each species were combined and applied to maps of distribution based on regional transect surveys.

Examples of wildlife sensitivity mapping

Wind farm Sensitivity Index for seabirds in the German North Sea (2/4)

Geographic scope	Regional
Renewable energy sector	Offshore wind
Taxonomic focus	Seabirds, Waders, Anseriformes (ducks, geese, swans)
Intended users	Planning authorities, Government agencies, Consultancies
Access	Fully restricted
Format	Static map in reports
Data sources	Species records
Factors contributing to the calculation of sensitivity	Biogeographic population size, Regional conservation status, Regional population size, Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Flexibility in species habitat use
Intended data update cycle	Unknown
Use in planning process	Developed by Government, not formally integrated within the planning process, paper regularly cited (best practice) and has informed multiple offshore wind planning maps.
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

Wind farm Sensitivity Index for seabirds in the German North Sea (3/4)

Data

Data from the European Seabirds at Sea Database version 3.0 (July 2002) and the German Seabirds at Sea Database version 3.06 (April 2003) were used in this assessment. Databases are described in Stone *et al*. (1995) and Garthe, Hüppop & Weichler (2002). All seabird species using the area, 26 in total, were included in the assessment, including divers, grebes and seaducks.

Analytical approach

Some nine vulnerability factors were included and divided into three groups, comprising (A) flight behaviour (flight manoeuvrability, flight altitude, percentage of time flying, nocturnal flight activity), (B) general behaviour (sensitivity towards disturbance by ship and helicopter traffic, flexibility in habitat use) and (C) status (biogeographical population size, adult survival rate, and European threat and conservation status). Each factor was scored on a 5-point scale from 1 (low vulnerability) to 5 (high vulnerability).

For each group, an average score of the respective factors was calculated, and these average scores were subsequently multiplied by each other to give the species specific sensitivity index (SSI) for each species. Black-throated diver *Gavia arctica* and Red-throated Diver *Gavia stellata* ranked highest (= most sensitive), followed by Velvet Scoter *Melanitta fusca*, Sandwich Tern *Sterna sandvicensis* and Great Cormorant *Phalacrocorax carbo*. The lowest values were recorded for Black-legged Kittiwake *Rissa tridactyla*, Black- headed Gull *Larus ridibundus* and Fulmar *Fulmarus glacialis*.

Seabird vulnerability was presented in maps with grids of 6′ latitude × 10′ longitude amounting to a total grid size of c. 120 km^2. Only data collected under good detectability conditions from January 1993 to May 2003 were included. Data were summarised per season. Coverage varied across the study area, so the data were corrected for different survey effort by dividing the total number recorded per grid cell by the total area. For each grid cell with sufficient data, the vulnerability for each species was determined as the SSI value multiplied by the natural logarithm of its density (+1, to avoid undefined values) and subsequently summed over all species. The final index for

Examples of wildlife sensitivity mapping

Wind farm Sensitivity Index for seabirds in the German North Sea (4/4)

each grid cell was defined as major concern using the 60th percentile, which was considered to be more conservative than using the 50th percentile (i.e. the median).

Additional features
NA

Uptake
NA

Effectiveness
This is not a planning tool and the map is only available as a published peer-reviewed paper. This paper has been cited widely in the development of other sensitivity mapping projects, including those by other countries associated with the North Sea.

Adaptability
The approach has been adapted several times and remains an important study in the development of sensitivity indices for seabirds.

References

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Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (1/7)

WWF Greece

Summary
The region of Thrace is of exceptional ornithological importance, hosting habitats that are of European-wide significance, mainly for large birds of prey. A large part of the region has been selected as priority area for the development of wind energy, as it is one of the areas with the highest wind capacity in mainland Greece. Specifically, the biggest part of the Regional Unit (RU) of Evros and a part of the RU of Rodopi have been delineated as Wind Priority Area 1 (WPA 1) under the National Renewable Energy Spatial Plan framework.

In an effort to determine the conditions that can lead to the sustainable development of wind farms in Thrace, WWF Greece drew up a proposal for the proper site selection of wind farms inside the WPA 1 (WWF Greece 2008). The proposal was updated in 2013 as a result of new data and changes in national environmental legislation that introduced important measures for the protection of bird fauna and other biodiversity.

The current soaring bird sensitivity map provides authorities, investors and other stakeholders with the information required to take well-informed decisions. The map divides the region into two distinct categories: 'Exclusion Zones' and 'Increased Protection Zones'. Exclusion Zones are locations where wind farm installation should be excluded. In contrast, Increased Protection Zones are locations where wind farm installation could be realised with appropriate mitigation in place.

Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (2/7)

Geographic scope	Regional
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Ciconiiformes (storks)
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Public
Format	Mapping interface, Static map, GIS Shapefile, Google Earth layer
Data sources	Species range maps, Species records, Conservation sites, Infrastructure maps
Factors contributing to the calculation of sensitivity	Proportion of regional population, Proportion of national population, Global conservation status, National conservation status, Species behaviour (flight height, degree of wariness etc.), Habitat Sensitivity (Nesting sites/ colonies)
Intended data update cycle	2-5 years
Use in planning process	Not required legally.
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (3/7)

Data

Data for Cinereous Vulture *Aegypius monachus* and Griffon Vulture *Gyps fulvus*, were derived from longstanding monitoring programmes, implemented by the permanent scientific team of WWF Greece in the area. These included data derived from visual observations, international literature, and field experience.

For Golden Eagle *Aquila chrysaetos*, Long-legged Buzzard *Buteo rufinus*, Peregrine Falcon *Falco peregrinus* and Black Stork *Ciconia nigra*, WWF included data on nesting locations both within and outside the Wind Priority Area 1 from historical observations and a field survey conducted during the summer of 2008.

Although birds are the focus of the map, a significant number of bat carcasses were also noted during mortality surveys—186 bats between 3/8/2009-4/8/2010, averaging 2.11 individuals per turbine. However, the limited data, especially regarding the population size of bats in the region, did not allow for a reliable evaluation of the long-term effects on bat populations from wind farms in the region. However, mitigation was recommended at turbines having caused bat mortalities (Georgiakakis *et al*. 2012). Recommendations suggested an increase to 5.5 m/s for minimum wind speeds for turbine operation between sunset and sunrise, as setting a minimum threshold has been shown to considerably reduce bat fatality rates with minimal loss of electricity production (Baerwald *et al*. 2009).

Limitations of the mortality data include the infrequency of carcass searches, variable observer efficiency, and the high removal rate by scavengers (e.g. cats and birds). Scavenger removal rates and observer efficiency trials were not conducted due to limited resources but these parameters should ideally be modelled to more accurately estimate the actual mortality rate at turbines. Estimates should also consider relief, vegetation and season separately for each wind farm. Rates of collision are also expected to vary with inclement weather, such as strong wind, rain and mist. These parameters should be included in risk assessments of areas of potential impact. A second follow-up study after 3-5 years will significantly improve the assessment of ornithological impacts and therefore the exclusion zones.

Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (4/7)

Analytical approach
The map proposes exclusion zones based upon the distribution of highly vulnerable bird species. The overall site selection overlaid areas of sensitivity for Cinereous Vulture and Griffon Vulture colonies, and Black Storks territories, along with national parks. These include:

- Core range areas consisting of high use areas, where Cinereous Vultures spend most of their time (75-100%) and common vulture flight corridors characterised as medium-high use areas (50-75%).
- The most common roosting areas.
- The most common feeding areas for young individuals.

In the future, it is intended to also include Egyptian Vulture *Neophron percnopterus* nest sites.

An Increased Protection Zone was additionally designated for Cinereous Vulture, which included medium-low use areas, where vultures spend less time but are still at risk.

Additional exclusion zones were also included:

- Two National Parks - Dadia National park and Evros Delta national park (Ramsar site).
- A Griffon Vulture colony: the most important colony in terrestrial Greece and site for communication between neighbouring colonies and feeding areas.
- Loutros pine forest: an important site for birds of prey and Black Stork.

Since the study, more accurate models have been produced to analyse range use and collision risk of Cinereous Vultures (Vasilakis *et al*. 2017).

Additional features
In addition to identifying exclusion zones, the study highlights the potential for wind development in Greece. It confirms that Wind Priority Area 1 is capable of contributing to the attainment of national renewable energy targets without adversely damaging the region's wildlife.

Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (5/7)

Uptake
The proposal and sensitivity map are being used by both developers and competent authorities during the design and assessment phase of wind farm projects in Thrace. It is regarded as providing a sound scientific basis for planning.

Effectiveness
This project provided tools to improve knowledge and understanding of potential impacts of wind farms. It has provided an opportunity to improve EIAs and Appropriate Assessments (AAs) as well as highlighting the need for additional studies. It has also led to the development of additional monitoring requirements for existing developments and collision-aversion technologies.

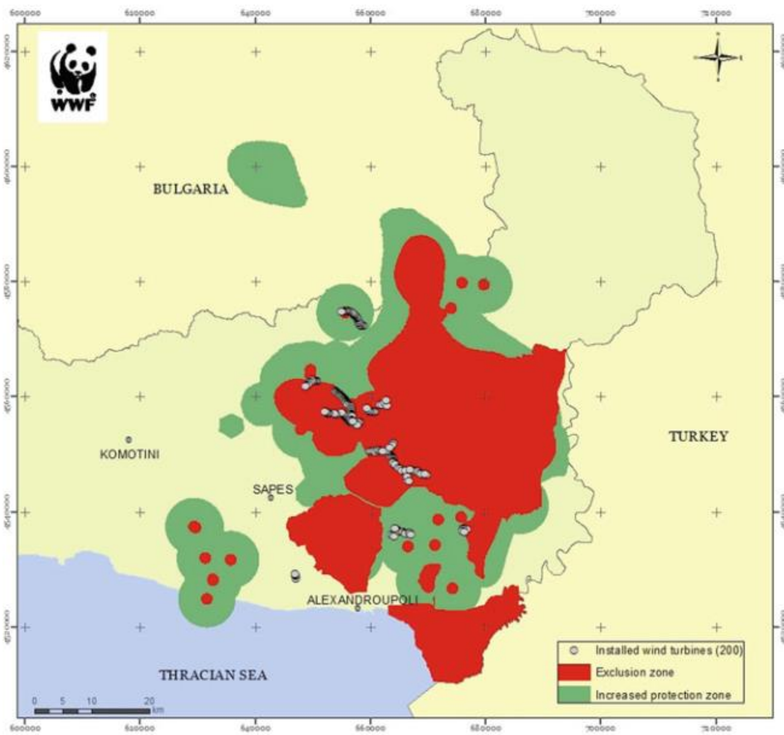
It was intended to include Egyptian Vulture nest data in the map, however this is currently pending awaiting the findings of a Species Action Plan. It is anticipated that in future there will be a 5km exclusion zones added around Egyptian Vulture nests. The other data in the survey is variable in quality and tracking information of the same calibre as that available for Cinereous Vultures would improve the maps accuracy, especially for species like Griffon Vulture.

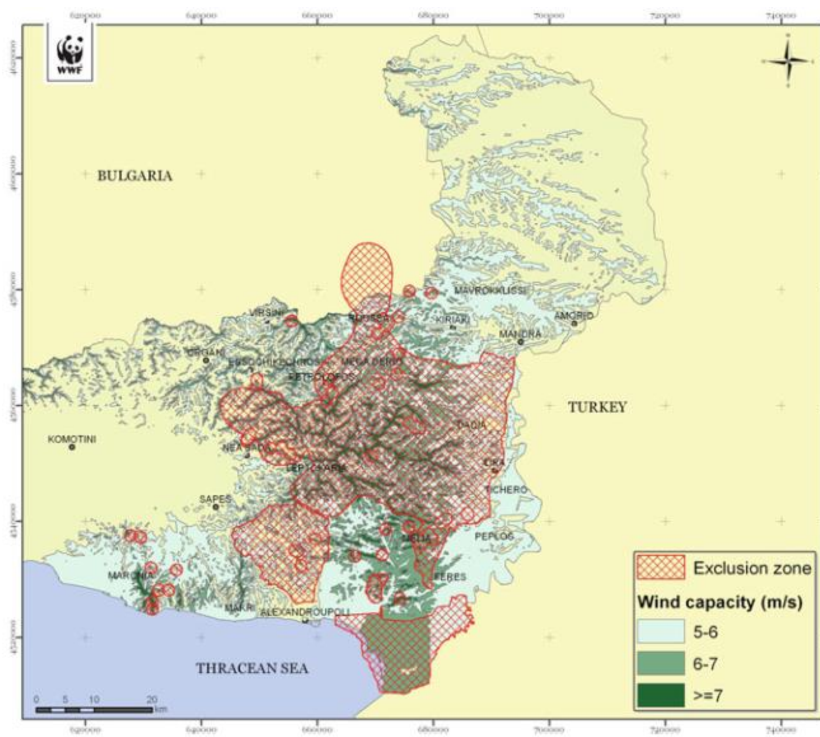
Adaptability
This tool provides useful insights into sensitivity mapping for localised populations of highly sensitive species and shows how core home ranges for species and nest sites can be used to delimit areas as highly sensitive to renewable energy development. It relies on high quality tracking data which is unlikely to be available for many species across a wider geographic scope. However, trying to replicate this at a national or international level would require a large number of additional considerations and datasets. As tracking data is not available for all sensitive species across the EU, other predictors of presence and landscape use will be required such as identification of migration routes, protected area boundaries and topographic features.

Following WWF's sensitivity mapping and proposal for proper site selection, additional research has focussed on the usage of the Eastern Rhodopes Mountains by Cinereous Vultures

Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (6/7)





Examples of wildlife sensitivity mapping

Soaring bird sensitivity map for wind energy development in Thrace (Greece) (7/7)

Aegypius monachus (Vasilakis *et al.*, 2016; 2017). Long-term satellite telemetry was used to produce a species-specific sensitivity map for guiding wind energy development, and to estimate the collision mortality caused by wind farms currently operating in the area. The results of this project went towards updating the recommendations for wind farm exclusion zones in the area and estimated a potential annual mortality from current wind farms of 5-11%, sufficient to lead to population-level declines.

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Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (1/7)

Bulgarian Society for the Protection of Birds (BSPB)

Summary
The Bulgarian Society for the Protection of Birds (BSPB) has developed a national wind sensitivity map, and a regional sensitivity map for Red-breasted Goose *Branta ruficollis*, in response to a rapid proliferation of wind farms in the region of Kaliakra in eastern Bulgaria. By 2010, 5,800 wind turbines had been built in Bulgaria, with 3,100 of these located in Dobrudzha.

The nationwide sensitivity mapping was carried out in 2013 and incorporated information on 41 species. The Red-breasted Goose sensitivity map was developed as part of an EU LIFE project between September 2010 and May 2015. It covers the Bulgarian region of Coastal Dobrudzha where the Red-breasted Goose is under existing pressure from hunting and human disturbance at important feeding grounds where they rely on crops during the winter.

The national maps delineate areas of High, Medium and Low Sensitivity for key migratory, wintering and breeding species in Bulgaria and overlay wind farm capacity layers projecting forward to 2020. The regional map depicts five levels of sensitivity based on areas of suitable feeding habitat, high flight activity and roost site importance.

Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (2/7)

Geographic scope	National/ regional
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Apodidae (swifts), Passerines
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public / partially restricted
Format	Static map, Geodatabase, GIS shapefile
Data sources	Species range maps, Habitat maps, Species records, Conservation sites, Infrastructure maps
Factors contributing to the calculation of sensitivity	Proportion of global population, Global conservation status (e.g. IUCN Red List), Distribution, conservation status, known impacts by wind turbines and additional spatial attributes, Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Habitat scarceness
Intended data update cycle	Hopefully in future
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (3/7)

Data

A total of 105 bird species were selected as target species for the determination of the key areas for migration, as well as during nesting and in winter. Forty-one of these were identified by the Ministry of Environment and Water (MoEW) as high priority for study and evaluation during migration and during the breeding period. In addition, three more species were identified as high priority during the breeding season (Annex I of the Birds Directive), as well as eight wintering waterfowl.

BSPB collated considerable additional data to underpin the map. In total, 115 fieldworkers took part in field surveys, amassing 4,633 person-days of survey effort. New surveys carried out included:

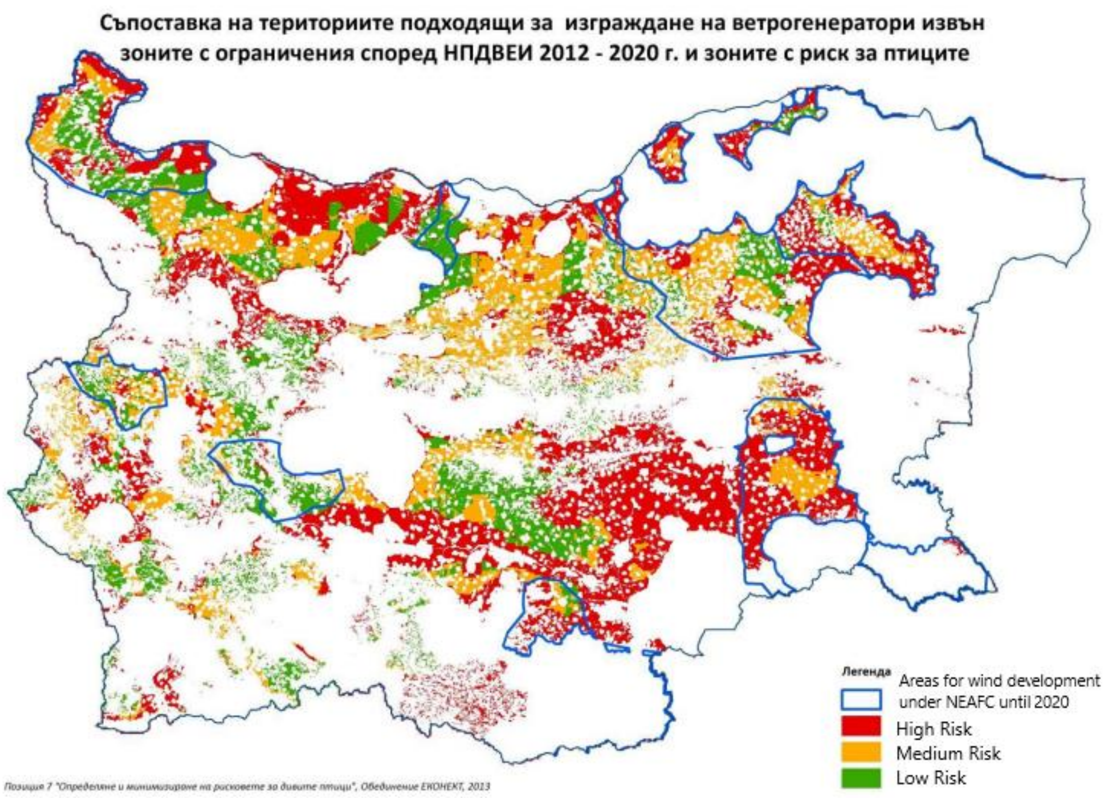
- The first national survey of the foraging areas of wintering geese in Bulgaria.
- Coordinated survey of wintering geese through the LIFE+ project "Safe grounds for the Red-breasted Goose (LIFE09/NAT/BG/000230)" during 2010/2011 and 2013/2014.
- The first national study of SPA's in Bulgaria.
- The first systematic radar study of local movements of breeding birds (www.buwa.nl/en/bird-migration-in-bulgaria.html).

Key areas for individual species and groups were identified using models of bird abundance and distribution combined with geographical considerations such as rainfall, land use etc. Risk maps were then created for each of the target species/groups, and for each season, based on the bird key area maps and data on recorded impacts e.g. collision and disturbance.

The regional Red-breasted Goose map incorporated multiple spatial elements of wind farm risk, for which data were obtained from targeted surveys identifying: collision risk (based on goose flight data collected during Vantage Point surveys), displacement risk (based on transect data and goose dropping counts) and roost importance (based on roost monitoring data). Twenty-two geese were tagged at three sites providing ten months of data. Substantial data on the local movements and connectivity between roost and feeding areas were collected.

Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (4/7)



Bulgarian sensitivity map highlighting the unsuitability of some areas identified for wind development in the period up to 2020 in the National Renewable Energy Action Plan.

Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (5/7)

Analytical approach
The risk maps were made by multiplying the predicted density per km-square with the risk assessment per species and then totalling this over all species. Contributing to the species risk assessment was an expert assessment and literature review, which identified risk factors, such as EU conservation status, reproductive capacity and generation length. In order to standardize the risk maps they were converted to seven levels of sensitivity.

The national sensitivity map has three categories:

1. **High risk** - area where the risk is identified as class 7 or 6
2. **Medium risk** - area where the risk is identified as class 4 or 5
3. **Low risk** - area where the risk is identified as class 1, 2 or 3

The final national sensitivity map combines three maps—breeding, wintering and migration. The map is based on 1 km square grid resolution. Buffers were created around bird nests according to knowledge of the species breeding season territories. For instance, some buffer zones used include: 50 km around Griffon Vultures *Gyps fulvus* colonies; 15 km around nests of Egyptian Vulture *Neophron percnopterus* and Eastern Imperial Eagle *Aquila helioco*; and 6 km around Golden Eagle *Aquilo chrysaetos* nests. In addition, 2 km buffers were created around wetlands with significant bird congregations or that host globally endangered waterfowl.

The final national risk map was combined with a wind energy capacity map, which mapped restrictions to wind farm construction, such as National Protected Areas, Natura 2000 and areas within 500 m of settlements, alongside wind resource, power line infrastructure and electricity demand.

For the regional Red-breasted Goose map, a 10 km buffer was chosen around known roosting areas, in acknowledgement of the region's importance for this species.

Various sources of data were used to create the Red-breasted Goose sensitivity map incorporating different elements of wind farm risk that were expected to be relevant in Coastal Dobrudzha: habitat displacement, collision risk and proximity to

Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (6/7)

56 important roost sites. Despite their existing protection as SPAs, roost sites were incorporated as an additional component of the sensitivity map to further highlight the need to protect these key sites for Red-breasted Goose. Three key areas maps for Red-breasted Goose were elaborated based on three key spatial elements—roosting sites, foraging areas and movement corridors/airspace. To create the sensitivity map, each of the three key areas were re-scaled to a proportional scale (0-1). A standard scaling system was applied to each of the three maps to represent the relative sensitivity score, from 1 (lowest) to 5 (highest). Individual maps were then amalgamated into a single map of overall sensitivity, by assigning each pixel of the output map the highest value from the three overlapping maps.

Additional features

The national map is available as a geodatabase at the MoEW. Many additional static maps that show the stages of development for the final map are available in the full report.

A GIS database of the Red-breasted Goose sensitivity map and contributing layers was produced and the map, with associated guidance on its use, was published in the document 'Guidance for good planning of development in the wintering grounds of the Red-breasted Goose'.

Uptake

Since 2013, the government has operated a zoning system for wind energy developments. Although it is only advisory, planning permission is more easily obtained within zones. BSPB's national sensitivity map has been adopted into national planning processes.

The GIS version of the Red-breasted Goose map was delivered to the MoEW. Governmental officials and also representatives of wind energy sector were trained to use the map. The map is available as a geodatabase at the MoEW and its regional outposts.

Effectiveness

The Red-breasted Goose project resulted in the first sensitivity map of its type, detailing at a fine resolution the sensitivity of a specific taxon of high conservation concern (Annex I species of

Examples of wildlife sensitivity mapping

Bulgarian wind farm sensitivity mapping (7/7)

the Birds Directive) in one of the species' strongholds. Overall, 40 % of the area is classed as 'high' or 'very high' sensitivity and 13% is classed as 'low' or 'very low' sensitivity.

The regional sensitivity map forms a good example of a practical modelling tool that could be applied by decision makers and EIA/ AA experts to assess the impact of certain project developments and different scenarios. This is the first interactive sensitivity map based on specific robust study in the country.

Adaptability

The overall sensitivity map exemplifies a nationwide approach to identifying sensitivity to a selected suite of species. It could be scaled up for a wider EU context as most types of data used in this study can be obtained for other countries with monitoring schemes. It shows a similar approach to other sensitivity maps (e.g. Vasilakis *et al*. 2017), whereby nest sites of high importance are incorporated into a map representing wider species movements. The map also overlays a wind resource layer representing the potential for development of wind turbines (National Renewable Energy Action Plan) until 2020.

This regional map is a key example of fine-scale mapping for specific species of concern. The types of data could be replicated for other species or taxa. However, there were substantial funds available to this project, which permitted a wide range of conservation issues to be addressed for the Red-breasted goose in Dobrudzha and data in this instance will be richer than for other species at risk in Europe. The map provides a good level of explanation.

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Conservation of the Wintering Population of the Globally Threatened Red-breasted Goose (*Branta ruficollis*) in Bulgaria. LIFE Project final report.

Examples of wildlife sensitivity mapping

Wind farm sensitivity mapping in France: A review of several regional approaches (1/7)

Summary
French wind energy planning formerly took place through nationally set "Wind Development Zones". In 2013, this was replaced by regional wind energy schemes. Many regional schemes have been turned down by the courts because of the lack of environmental assessment. Today, only national parks, nature reserves and sectors delimited by biotope prefectural decrees can be excluded from the development of wind power. Other important sites, such as Natura 2000 sites, IBAs and Ramsar sites are treated on a case-by-case basis, where thorough impact assessments are mandatory before permissions are granted. Further, decentralized state services in the regions (DREAL) sometimes draw up maps of biodiversity issues to be considered by wind energy developers.

To illustrate progress to date, the details of approaches taken in Grand Est and Pays de la Loire are profiled. In addition, another example adopted by the Department of Indre, which is within the Centre-Val de Loire Region, is also illustrated (despite its relatively localised application) on the basis that it applies a unique methodology for the assessment of impacts on bats.

Examples of wildlife sensitivity mapping

Wind farm sensitivity mapping in France: A review of several regional approaches (2/7)

Data
Underlying datasets vary for the regional approaches:

<u>**Lorraine**</u>
The project provides an assessment of bird and bat sensitivity to windfarm development using datasets relating to protection zones, breeding bird distribution and bat roosts. The information is presented in several separate maps and also assimilated into one combined map illustrating the areas of highest sensitivity within the area.

Sensitivity zones are based on three principal aspects:

1. Important sites for birds and bats.
2. Information available on nesting bird species known to be susceptible to the impacts of turbines.
3. Information on the distribution of bat species known to be susceptible to the impacts of turbines.

The following data sources were included in relation to important sites:

- All Special Protection Areas (SPAs);
- Special Areas of Conservation (SACs) of ornithological interest (presence of species in Appendix I of the Birds Directive and other qualifying species);
- Chiropterological SACs (presence of at least one species of Annex II of the Habitats Directive);
- Important Bird Areas (IBAs), including those that have not so far become SPAs;
- Prefectural Biotope Protection Orders (APPB);
- Ramsar sites;
- National Hunting and Wildlife Reserves (RNCFS);
- Voluntary Natural Reserves (NVR) and Regional Nature Reserves (RNR) of ornithological and / or chiropterological interest;
- All Natural Areas of Ecological Interest, Fauna or Floristic (ZNIEFF).

Avian data come from the databases of the Centre Ornithologique Lorrain (COL) and Neomys. For some species, other specialists were consulted. Information available from neighbouring regions or countries were sought and, where appropriate, integrated into the development of the maps (e.g.

Examples of wildlife sensitivity mapping

Wind farm sensitivity mapping in France: A review of several regional approaches (3/7)

Alsace, Champagne-Ardenne, the Grand Duchy Luxembourg and Wallonia).

Bat data came from a database managed by CPEPESC-Lorraine. As with the bird data, information available from neighbouring regions or countries was sought and integrated within the map (e.g. Franche- Comté, Alsace, Champagne- Ardennes, Wallonia, the Grand Duchy of Luxembourg and the Saarland in Germany).

Pays de la Loire

This project set out to identify areas within the Loire Valley region that are suitable for wind development, while taking into consideration sensitivities relating to biodiversity, the environment and heritage, as well as technical constraints, such as airports. The dynamic map includes data relating to protected areas, Natura 2000 sites, Ramsar sites, IBAs, Biotope Protection Order sites, zoning of archaeological sites, heritage sites and existing and planning wind farms. Additional data layers, identifying critical areas for birds and bats, are described further under 'Analytical approach'.

Indre

A study compiling information on the distributions of bats from observations made between 1987 and 2008. The biology of each species and known mortality from windfarms was compiled to examine sensitivity.

Data were compiled from various inventories of bats produced since the 1980s. Hundreds of observations were reported in each year between 1988 and 1991, with smaller numbers each year up to 2004. Records since 2005 were boosted as a result of a new project and the greater availability of bat detectors. Observations ranged from counting individuals at their breeding and winter roosts, as well as general monitoring of their hunting activities in the wider countryside.

Analytical approach

The approaches to sensitivity assessments undertaken in each of the tools are summarised as follows:

Lorraine

A hierarchy was identified for the protection zones, with those

Examples of wildlife sensitivity mapping

Wind farm sensitivity mapping in France: A review of several regional approaches (4/7)

likely to reflect areas of greater concern afforded higher sensitivity scores. The bird and bat species included were determined based on a detailed assessment of the literature. In total, 24 bird species and nine bat species were taken into account. Species were considered based on their conservation status and likelihood of collision, derived from European collision data. Each species was assigned a sensitivity score. For bird species where precise presence data were available, buffers of decreasing sensitivity were drawn around the breeding sites determined by the home range of the species. When less precise data was available, an area of diffuse presence was defined based on regional distribution data. For bats, buffers were drawn around known colonies.

Three maps were produced - for “very high”, “high” and “medium” risk areas (low risk areas constituting the remainder). The overall risk level was determined as the sum of sensitivity scores across these layers. Separate map layers were produced depicting important sites.

<u>Pays de la Loire</u>

The sensitivity map included site data relating to habitat, biotopes and nature reserves. Natura 2000 and Ramsar sites were not automatically excluded, however, their significance for birds and bats was recognised, and a specific sensitivity analysis was commissioned. That study resulted in the exclusion of most of the SPAs and all of the Ramsar sites from the final map. Species sensitivity was classified as ‘Very high’, ‘High’, ‘Medium’ and ‘Low’ based on the species threat status, both nationally and regionally (and considered separately for breeding, wintering and passage populations) and the species relative abundance (the proportion of the national population within Pays de la Loire). The data used to create the bird maps were derived from breeding surveys as well as the locations of significant habitats stopovers used during the migration period.

For bats, breeding season data was not used because of known sampling bias. Instead, the bat map was based on the location of roosts, and known information about home ranges weighted by a species’ sensitivity to wind turbines, and included suitable habitats located nearby such as the forests, hedgerows, rivers,

Examples of wildlife sensitivity mapping

Wind farm sensitivity mapping in France: A review of several regional approaches (5/7)

wetlands, coastline and nature reserves.

Indre (Department)
All bat observations were included in the assessment. Sites were scored in order of importance, based on factors including European and national conservation status, roost type and abundance. Buffers were assigned to sites in accordance with relative importance (departmental = 3km, regional = 5km, national = 7km and international = 10km).

Furthermore, an assessment of habitat importance was conducted based on published literature. It was illustrated from Corine map data, with rankings from 'Very favourable' to 'Not favourable'. The final recommendations were that the final map should be taken into consideration by windfarm developers, that developments within areas zoned as internationally important and/or in favourable habitats should be discouraged, and that further detailed impact assessments were required.

Additional Features
The various regional maps are available via a number of project reports and online tools.

The interactive maps for the Grand Est region, which includes the regions of Lorraine and Alsace, as well as Pays de la Loire, also provide information on the locations of existing and proposed wind turbines.

The Pays de la Loire map illustrates all windfarms in the region, together with their current status (constructed, planned, refused, etc.). There are also selectable layers for a range of nature conservation constraints, such as national parks, nature reserves and Natura 2000 sites.

Uptake
Whilst the use of these studies by developers is not mandatory it is expected that these tools are widely used during pre-planning and planning phases.

Effectiveness
The uptake and effectiveness of the maps vary across each region. All the approaches make use of information on nature

Examples of wildlife sensitivity mapping

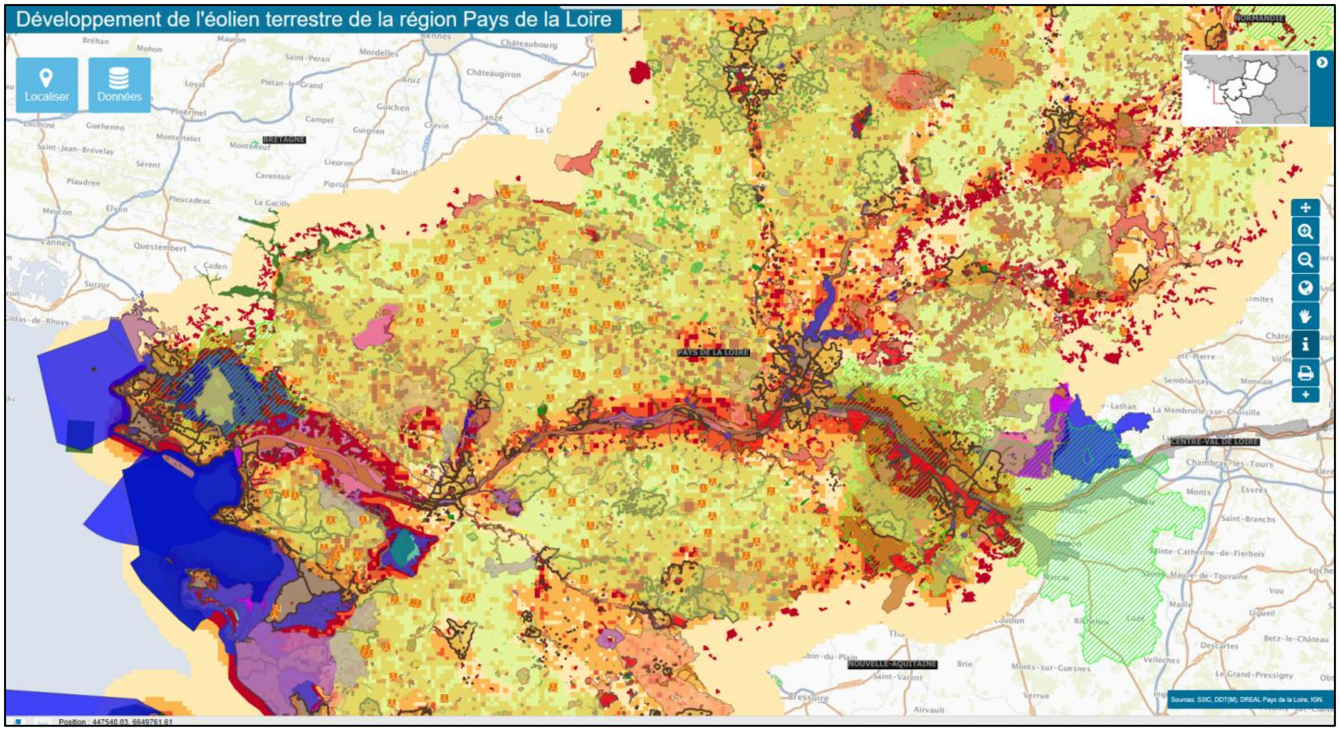
Wind farm sensitivity mapping in France: A review of several regional approaches (6/7)

protection zones, and/or on the distributions of relevant biodiversity and all provide a sound assessment of sensitivity. However, there is certainly scope for clearer national level instruction on the development and application of such maps. It would be beneficial for all regions to use similar, comparable methodologies, employ standardised datasets and follow consistent guidance on usage.

Adaptability
Each regional approach is developed to serve specific local circumstances, however, collectively they could be used to inform a national approach.

Examples of wildlife sensitivity mapping

Wind farm sensitivity mapping in France: A review of several regional approaches (7/7)



Screenshot from the Pays de la Loire sensitivity tool.

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (1/9)

Natural England, Marine Management Organisation, WWT Consulting and MacArthur Green

Summary
The Geographic Information System tool, SeaMaST (Seabird Mapping and Sensitivity Tool) was created to provide evidence on the use of sea areas by seabirds and inshore waterbirds in English territorial waters, mapping their relative sensitivity to offshore wind farms. It is a freely available resource intended for use by the offshore wind industry and marine spatial planners.

The tool utilises high-quality seabird survey data gathered during surveys at sea. Sensitivity scores were generated separately for collision and displacement. The tool combines Species Sensitivity Indices (SSI) for marine bird species with a Density Surface Model (DSM) which generated a density for all 3 x 3 km grid cells within English waters, and out to a maximum of 200 nautical miles.

The tool is freely available as a GIS resource alongside detailed information explaining the methodology. To date, the tool has been promoted for use in informing wind farm development and marine spatial planning. While the map has not formally been integrated within the planning process, it is regularly used by relevant authorities, NGOs etc.

The SeaMaST tool is based on a combination of high-quality data, and on proven methods, and has resulted in a high-quality sensitivity map for seabirds in English Territorial Waters.

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (2/9)

Geographic scope	Regional
Renewable energy sector	Offshore wind
Taxonomic focus	Seabirds, Waders, Anseriformes (ducks, geese, swans)
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public
Format	GIS shapefiles, static maps in reports
Data sources	Species range maps
Factors contributing to the calculation of sensitivity	Proportion of regional population, National conservation status, EU conservation status (Nature directives), Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Habitat displacement vulnerability
Intended data update cycle	> 10 years
Use in planning process	Developed by Government, not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs)
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (3/9)

Data
The study included all marine waters from the mean low-water mark of the English coast out to a maximum of 200 nautical miles (or to the neighbouring territorial waters boundary). The analyses were based on two main datasets:

- *European Seabirds at Sea (ESAS)*: database held by the Joint Nature Conservation Committee, with more than 310,000 records from the area from 1979 – 2011, predominantly from boat-based surveys. The survey was based on records of sitting birds in 300m line transects, and birds in flight were recorded every 10 minutes. It should be noted however that some species are known to avoid boats (seaducks and divers), whilst others are attracted (gulls and gannets). This was to some extent addressed through forward scanning and snapshots. Full methodological details are presented in Camphuysen *et al.* (2004).

- *Visual aerial survey data*: collated by the Wildfowl and Wetlands Trust (Consulting) Ltd., with more than 400,000 seabird records from surveys undertaken between 2001 and 2011. These surveys also employed a transect-based method, and all sitting and flying birds were recorded in four distance bands (out to 1 km), thereby facilitating improvements to density estimates. The survey altitude was maintained at 76m. The aerial method was advantageous over boat-based methods allowing coverage of larger areas, whilst movement of birds is less. Although it was acknowledged that aerial surveys do result in lower identification rates. Further discussion on the comparison of boat and aerial-based surveys is presented elsewhere (Camphuysen *et al.* 2004).

Additionally, data came from surveys undertaken in relation to offshore wind farm development through the Crown Estate Data Catalogue. Additional data sources included tracking studies, the Wetland Birds Survey (WeBS) and seabird colony counts.

The tool includes data on a range of bird species that are dependent on the offshore marine environment and are potentially susceptible to the effects of offshore wind energy

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (4/9)

development through direct collision, and/or through displacement. The timing of these effects is year-round, with 25 breeding seabirds potentially affected during breeding season months, and others (e.g. wintering divers, grebes, seaducks) potentially affected outside the breeding period.

The tool currently contains information on 53 species from the following families— Anatidae (ducks), Gaviidae (divers), Podicipedidae (grebes), Procellariidae (fulmars), Hydrobatidae (storm petrels), Sulidae (Gannet), Phalacrocoracidae (cormorants), Scolopacidae (sandpipers), Stercorariidae (skuas), Laridae (gulls), Sternidae (terns) and Alcidae (auks).

Analytical approach

The datasets were first used to create a Density Surface Model (DSM), generating densities for all 3 x 3 km units within the region. DSM uses Generalised Additive Models (GAMs) or Generalised Additive Mixed Models (GAMMs) to fit functions to the data using locational and environmental covariate data to predict modelled abundance. The 'soap film smoothing' technique was added to account for the complex coastline, thereby preventing erroneous predictions, such as higher densities across headlands. Prior to the DSM analyses, the transect data were corrected for detectability using the Distance analysis (Miller 2012).

Sensitivity scores were generated based on six aspects of species behaviour called 'species vulnerability factors', which included: flight altitude, flight manoeuvrability, percentage of time flying, nocturnal flight activity, disturbance by wind farm structures, ship and helicopter traffic, and habitat specialisation.

Four factors representing conservation importance were also used. These are described below with coefficients in parentheses:

- Status in relation to the Birds Directive (a): Emphasis was given to species considered by the European Commission to be in particular need of conservation protection, especially those listed in Annex I. Accordingly Annex I species were scored 5, migratory birds which are features of SPAs were scored 3, and other marine species scored as 1.

- Percentage of the biogeographic population that occurs in England/English waters during any particular season (taking account of turnover of individual birds) (b): These

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (5/9)

were scored 5 (species with more than 20% of the biogeographic population occurring in English waters), 4 (10-19.9%), 3 (5-9.9%), 2 (1-4.9%), 1 for all other species.

- Adult survival rate (c): This was based on published information on data survival which reflects vulnerability of a species to an increase in mortality above natural mortality. Generally species with lower adult survival rates tend to breed earlier and have high reproductive output and are less vulnerable to additional mortality when compared with longer lived species with lower reproductive output. Adult survival rates were classified following the banding used by Garthe and Hüppop (2004): 1 (adult survival < 0.749), 2 (adult survival 0.75-0.799), 3 (0.80-0.849), 4 (0.85-0.899), 5 (adult survival > 0.90).

- UK threat status (d): This reflects both threat and conservation status of the species in the UK (Eaton *et al.* 2009) in 'Birds of Conservation Concern 3' (BOCC3). BOCC2 was also considered given some differences between the two periods. This category was scored as 5 (Red-listed), 4 (Amber listed BOCC2 or BOCC3), 3 (Amber BOCC3, green in BOCC2,), 2 (Amber BOCC2, green in BOCC1,), 1 (Green in BOCC3 and BOCC2).

The vulnerability factors were also scored from 1 to 5, with 5 reflecting a strong anticipated negative impact. For most, the scores were adopted from Garthe and Hüppop (2004) and adjusted where more recent data suggest appropriate:

- Flight altitude (e): Flight altitude is considered to be of significant importance in determining the risk of collision, and includes birds in all activities (foraging, commuting and migrating), and it may vary seasonally, with moult, with behaviour and with location.

- Flight manoeuvrability (f): This factor accounts for the agility of species, and their ability to avoid a potential collision.

- Percentage of time flying (g): It is assumed that species that spend more time in flight (whether it be during breeding, migrating, wintering etc.) are more vulnerable to collision. The scores were based on activity budgets, based on estimated proportions of time spent flying.

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (6/9)

- Nocturnal flight activity (h): Detailed data on nocturnal flight activity are limited for many species, although increasing tracking studies are starting to improve this information deficit. The scores adopted by Garthe and Hüppop (2004) were adopted and included other published studies where available.

- Disturbance by wind farm structures, ship and helicopter traffic (i): Marine birds vary in their reactions to the presence of offshore wind farms, and to the increased ship and helicopter traffic associated with development and maintenance. This was scored from 1, reflecting limited escape behaviour and very short flight distance when approached t 5 reflecting strong escape behaviour, at a large response distance.

- Habitat specialisation) (j): Species with specific marine habitat requirements, feeding over very specific habitat features (e.g. shallow sandbanks with bivalve communities) were scored 5, compared with those more generalist and capable of foraging over large marine areas and with little association with specific marine features.

Collision risk and Disturbance/ displacement risk scores were generated for each species separately as follows:

1. Collision risk score (SSI (collision)) = e x (f + g + h)/ 3 x (a + b + c + d)
2. Disturbance/ displacement risk score (SSI (disturbance)) = ((I x j) x (a + b + c + d)/ 10

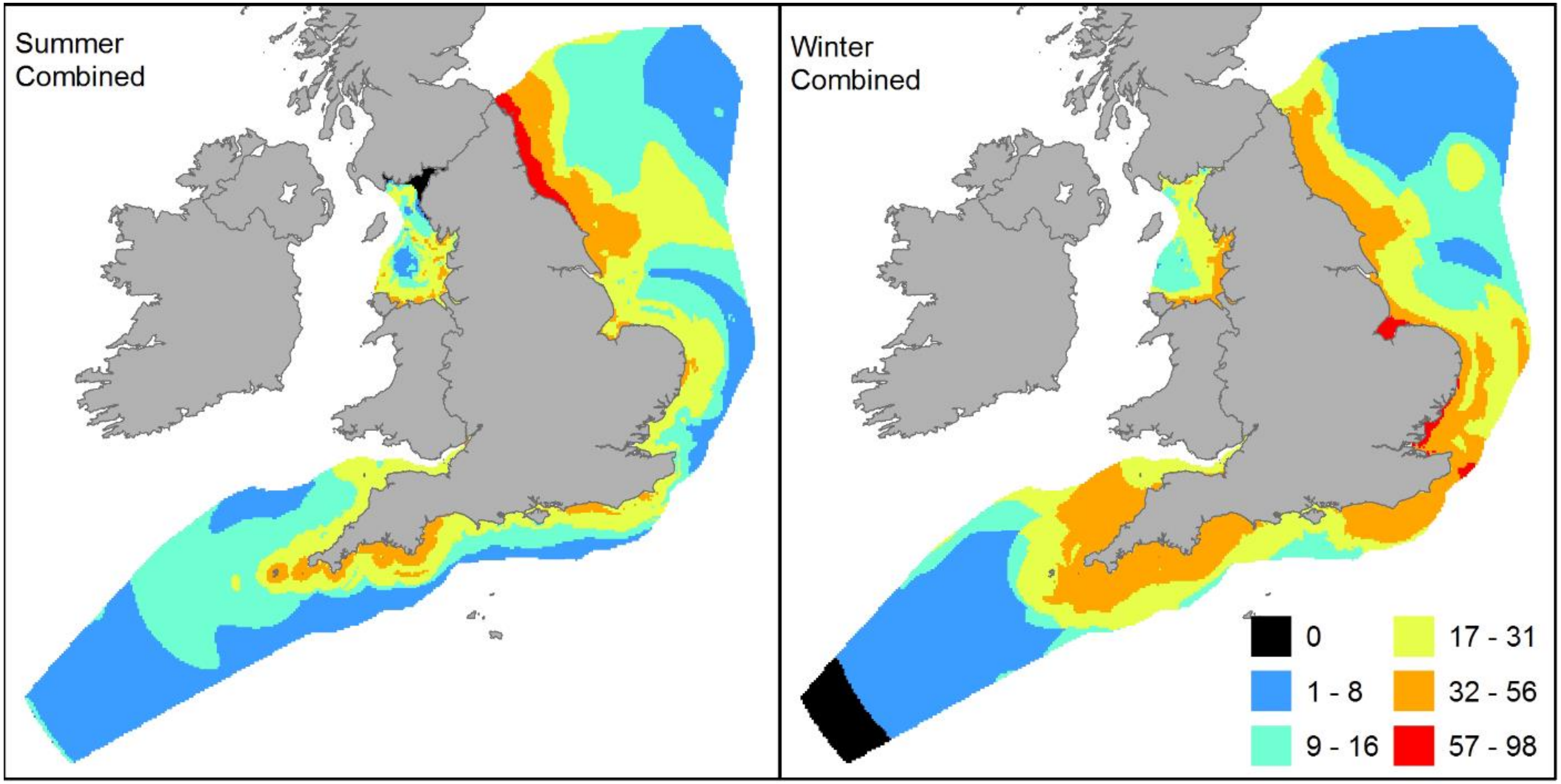
Where SSI is the Species Sensitivity Index, and coefficients a – i are described above, and a – d referring to conservation factors and e – I vulnerability factors.

Sensitivity mapping scores were applied to a function of the density of each species in each 3km x 3km grid cell. The natural logarithm of the density was used as it enables better scaling for comparison between species and areas. The Wind farm Sensitivity Index (WSI) was calculated as follows:

3. WSI (collision) = ln (density + 1) x SSI (collision)
4. WSI (disturbance/ displacement) = ln (density + 1) x SSI (disturbance)

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (7/9)



Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (8/9)

Additional features
While the tool is not yet available in an online interactive platform, the reports are readily available and the datasets are available in GIS format upon request.

Uptake
The tool was developed as part of the Marine Management Organisation (MMO) spatial planning, and is also used for strategic assessments of renewable energy planning, within project level assessments, research, marine protected area proposals.

This tool has been widely promoted within the UK. While it is currently used by a range of interested parties, there are no known examples where it has been used in the appropriate siting of wind farms.

Effectiveness
This tool is based on high quality and relatively large seabird datasets, mostly from transect-based surveys conducted at sea. The data were modelled to generate density surface models for English waters. Sensitivity scores were generated using information from evidence-based sources, especially published literature, and were applied to a 3x3 km grid to generate separate and combined sensitivity maps for collision and displacement. The tool therefore presents a relatively good assessment of risk associated with the offshore wind farm industry, and in relation to marine spatial planning for English waters.

Adaptability
The tool could be readily extended to additional areas and/or species groups, and to other sectors (e.g. wave and tidal energy). The method for calculating sensitivity is based on standard approaches taken in the development of several other terrestrial and offshore tools, especially those of Furness & Wade (2012, 2013), in generating scores based on some combination of conservation measures, occurrence, and likelihood of impact based on the species' ecology.

The method is dependent on the availability of high-quality survey data within the marine environment, which is limited in many countries. It is possible to update the model over time as the availability of data increases. Furthermore, the method is sufficiently flexible to facilitate inclusion of other types of datasets in the scoring process (e.g. Natura 2000 sites).

Examples of wildlife sensitivity mapping

SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm impacts in English territorial waters (9/9)

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Examples of wildlife sensitivity mapping

Regional locational guidance for wave and tidal energy in the Shetland Islands (UK) (1/6)

NAFC Marine Centre, University of the Highlands and Islands

Summary
The Scottish Government has set a target of 30% of total energy demand to be met by renewable sources by 2020. The Shetland Regional Locational Guidance (RLG) is a sensitivity led approach for identifying the suitability of areas around the Shetland Islands for renewable energy development. In this study, a spatial model was developed for the RLG showing potential areas of lowest conflict between existing uses and values and renewable energy developments. The study focussed at two levels, identifying and modelling constraints to development at sea separately from those related to cable landing sites at the coast.

All renewable developments are required to use the model. At present, the industry is in its infancy and consequently no sites have yet been licenced. It has however been used by developers in the scoping stage. These are typically developers whose technology has not subsequently succeeded or who are currently speculating on future growth (e.g. floating offshore wind).

Examples of wildlife sensitivity mapping

Regional locational guidance for wave and tidal energy in the Shetland Islands (UK) (2/6)

Geographic scope	Regional
Renewable energy sector	Wave/tidal
Taxonomic focus	Seabirds, Waders, Anseriformes (ducks, geese, swans), Cetacea (whales, dolphins, porpoises), Pinniped (seals), Other marine species
Intended users	Planning authorities, Government agencies, Consultancies
Access	Public
Format	Static map, GIS shapefile, Google Earth layer
Data sources	Species records, Habitat maps, Conservation sites, Infrastructure maps
Factors contributing to the calculation of sensitivity	Global conservation status (e.g. IUCN Red List), Regional conservation status, National conservation status, EU conservation status (Nature directives), Habitat sensitivity, scarceness and national protection status
Intended data update cycle	2-5 years
Use in planning process	Map developed with a government agency. Map formally integrated within the planning process with its use mandatory. Map linked to policy which requires its consideration
Percentage of siting decisions in which the tool is utilised	81-100%

Examples of wildlife sensitivity mapping

Regional locational guidance for wave and tidal energy in the Shetland Islands (UK) (3/6)

Data
The model was based on a variety of datasets related to the features most likely to be affected by the developments (a process informed by stakeholders consultation). As a result, the constraints map is highly refined and an accurate reflection of the most sensitive areas. Some of the datasets may be quite old (e.g. Seabird 2000) which could be of significance in an area where there has been significant changes in recent decades (e.g. breeding seabird populations).

The tool is based on the following data considerations:

Constraints at sea

- Aquaculture (Fin Fish) sites (Shetland Islands Council): Data available from SMSP.
- Aquaculture (Horse Mussels Modiolus modiolus & Maerl Phymatolithon calcareum.) sites (Shetland Islands Council): Data available from SMSP.
- Cables (KIS-CA; Shetland Islands Council): Data available from SMSP.
- Cetaceans (Shetland Amenity Trust): Data available from SMSP.
- Demersal fishing (Marine Scotland): Data available from SMSP.
- Dredge and disposal grounds (Lerwick Port Authority; Natural Capical; UKHO): Data available from UKHO.
- Important species and habitats (PMFs) (various sources): Data available from SMSP.
- Local policy development restrictions.
- National Scenic Areas and Local Landscape Areas.
- Nature Conservation Designated Areas (Natura 2000, Ramsar, PAs).
- Pipelines.
- Recreational use.
- Seabirds.
- Seals (at sea congregations).
- Shellfish fishing.
- Shipping routes.
- Waste-water discharge and water abstraction.
- Wrecks and Historic Marine Protected Areas.

Examples of wildlife sensitivity mapping

Regional locational guidance for wave and tidal energy in the Shetland Islands (UK) (4/6)

Constraints at the coast

- Archaeology.
- National Scenic Areas and Local Landscape Areas.
- Nature Conservation Designated Areas.
- Eurasian otter *Lutra lutra* distribution.
- Recreational use.
- Seabirds.
- Seals (protected haul-outs, nursing and pupping areas).
- Wildness.

Analytical approach

Stakeholder consultation resulted in the identification of constraints layers within the spatial model. So the model only considers features that are potentially negatively affected by marine renewable developments. The level and spatial extent of each of the constraints was determined in consultation with the stakeholders; the levels ranged between 1 to 0, and the spatial extent was variable reflecting a buffer around the constraint, or the extent of its distribution where available. Areas of exclusion were assigned a value of 4, and some areas designated for nature conservation were assigned a 2 due to their legal protected status. Constraint layers for all constraints within each of the sub-models (coast and at sea) were summed within each with equal weightings applied to create the full model output. However, stakeholders felt that it was difficult to interpret a continuous spectrum of values ranging from low to high. So constraint levels were assigned to one of 4 levels (Low, Medium, High, Very High) and the decision on the value between Low and Medium was chosen with careful consideration and consultation (Medium, High and Very High constraint levels require mitigation). These values were then summed to give an overall constraints layer based on these four categories, and for each of the sub-models.

Using a simple algorithm based on clear, known parameters, the tool presents a single map of sensitivity for each of the sea and coastal sub-models. The overall constraints are clearly represented by four sensitivity levels (Low, Medium, High, Very high). The nature conservation sensitivity was based on conservation importance, wherein areas of higher conservation value were given higher weightings in the model.

Examples of wildlife sensitivity mapping

Regional locational guidance for wave and tidal energy in the Shetland Islands (UK) (5/6)

The analyses integrates a variety of constraints altogether (including those relating to the fishing industry etc.). While the effectiveness of the model was tested by adjusting the weightings, it would seem that developing a similar model based solely on those related to nature conservation would deliver a wildlife-specific constraints map that might be quite different to the overall map. The constraint levels were qualitative and based on the consultation. The result could prove subjective and is highly dependent on the stakeholders included in the consultation. This may affect the adaptability of the tool and the extent to which its methodologies could be applied elsewhere.

Additional features
The map is available in GIS format, as a Google Earth layer and as static maps.

Uptake
It is anticipated that all renewable developments will use the tool, however, the industry is in it's infancy and no sites have yet been licenced.

Effectiveness
The tool provides a good summation of existing data on a variety of environmental variables that are of significance in the area (seabirds, seals, etc.), including those most vulnerable to the impacts of wave and tidal energy. The tool is most readily available as static maps within the published paper, and there are therefore limitations associated with investigating the details at a finer spatial scale, although a Google Earth layer is available upon request.

However, a number of data gaps were identified. The data used for breeding seabirds were gathered during Seabird 2000 (between 1998 and 2002) and are out of date. This is of significance as it relates to a group of birds whose trends have undergone massive change in recent decades, especially in the North Sea, due to declines in food availability. There are coverage issues relating to data on other environmental features, while spawning and nursery grounds of commercial stocks are not mapped. Gaps also exist in relation to data covering the socio-economic dependency on fishing grounds.

Examples of wildlife sensitivity mapping

Regional locational guidance for wave and tidal energy in the Shetland Islands (UK) (6/6)

The tool is focussed on appropriate siting of wave and tidal energy development assessment can only form part of a siting decision and do not replace the need for adequate EIAs.

This is one of the few tools that has been developed to inform the siting of wave and tidal energy development. It is also one of the few whose use is mandatory. The tool incorporates a broad variety of variables that includes environmental, social and economic factors.

Adaptability

The tool could be readily extended to additional areas and could be developed to generate sensitivity maps for other renewable sectors (e.g. wind) and other taxa. Indeed, the approach, or at least the basis of it (calculating and summing sensitivities spatially) is already being used elsewhere. The authors acknowledge that one of the key values of the model is that it is designed to accommodate change as new data and information becomes available.

References

Tweddle, J. F. Marengo, I., Gray, L. and Shucksmith, R. (2014) Developing regional locational guidance for wave and tidal energy in the Shetland Islands. *Marine Policy* 50: 53–66.

Examples of wildlife sensitivity mapping

Israel national wind farm sensitivity map, based on distributions of birds and bats (1/3)

Israel Nature and Parks Authority, Israeli Ministry of Environment, Society for the Protection of Nature in Israel, Jewish National Fund, University of Haifa and University of Tel Aviv

Summary

The sensitivity map for Israel was created in 2017 and is the first example of a wildlife sensitivity map in the country. In addition to assessing data for 61 bird species, the map incorporates bat sensitivities for 33 species, a larger extent than many other sensitivity mapping projects and produces a well-categorised set of maps and GIS layers. The website and accompanying documents are only available in Hebrew.

Data

The data used in the map are current and widely agreed on by relevant national experts. Bat data is limited to colonies and distribution models rather than actual observations.

Analytical approach

Species were selected by a team of national experts according to the potential risk from wind farm infrastructure. Risk was calculated by (a) national and international conservation status and (b) proportion of the number of individuals of the different species that pass by/winter in Israel out of their overall population size in their origin countries (Euro-Asian relevant distribution range). The analytical methods used are standard, taking inspiration from other sensitivity mapping projects in South Africa and Ireland. The project took into account species data, as well as habitat risks, and was able to assign sensitivity using a resolution of 5 km^2.

Additional features

An uncertainty level is calculated for the scores assigned to each grid square because some estimates were based on expert opinion in cases where data were lacking.

Additionally, threshold mortality rates for wind farms were calculated for a selection of the bird species in order to

Examples of wildlife sensitivity mapping

Israel national wind farm sensitivity map, based on distributions of birds and bats (2/3)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of prey, Seabirds, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Otididae (bustards), Other
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, Investors
Access	Public
Format	Static maps and GIS layers
Data sources	Species range maps, Species records, Habitat maps, Migration routes, Conservation sites, Expert consultation
Factors contributing to the calculation of sensitivity	Species population size (proportion of global and national populations), Conservation status (global and national conservation status), Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Habitat sensitivity and scarceness
Intended data update cycle	2-5 years
Use in planning process	Map developed with a government agency. Not formally integrated within the planning process, but recommended by authorities and NGOs.
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

Israel national wind farm sensitivity map, based on distributions of birds and bats (3/3)

determine a level of wind farm related mortality, beyond which action and mitigation would be mandatory and enforced for those wind farms. Certain rare species were given a higher priority and therefore no mortality would be permissible.

Uptake

The map is not adopted by planning authorities or the Ministry of Energy. Within Israel, regions (including the Northern region where there is most wind resource and many wind farms in the planning pipeline) make wind farm planning decisions at a large scale. Planning authorities consider several wind farms simultaneously within the same region of development. This should favour the increased use of sensitivity mapping and the Israeli Nature and Parks Authority, Ministry of Environmental Protection and SPNI are pushing for the further adoption of the map and recognition of its outputs.

Effectiveness

The map was developed with additional impetus from the Israel Greenhous Gas emissions reduction (mitigation) plan whereby one of the measures described 'Completing a bird sensitivity map in order to increase the certainty in locating wind energy electricity-generating facilities'.

The degree to which the map is considered is still being determined, but developers and investors are not yet routinely using the maps. Furthermore, the use of sensitivity mapping has been more focussed towards highlighting areas for mitigation rather than pre-planning avoidance.

The map is currently presented in a GIS shapefile format rather than an interactive platform; therefore, it is less accessible to the public than may be desired.

Adaptability

The map is expected to be updated as new data sources and information becomes available. The maps provide good initial consideration of on-site avoidance in relation to bats and migratory birds. The methods of considering multiple taxa in this project are promising and hopefully there are continuing developments in future iterations of the maps.

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (1/8)

VENBIS project, Ministry of Environment, Lithuania.

Summary

This sensitivity mapping project stemmed from the Development of Wind Energy and Important Areas for Biodiversity (VENBIS) project in Lithuania, supported by the Ministry of Environment. The project sought to evaluate the possible effects of wind energy development for biodiversity, with particular consideration of 69 breeding and 43 migratory bird species and 17 bat species, which were deemed sensitive to wind energy. Potential conflict areas were detected and solutions for managing biodiversity conservation and sustainable development of wind energy were proposed.

The analysis incorporated data on the distribution, conservation status and sensitivity of birds and bats to wind power with a concurrent evaluation of wind resource (modelled wind speed), special planning status of wind farms and technical considerations for wind energy development.

Data

Wind data were derived from hourly wind measurements at 10m height at 18 meteorological stations across the country over the course of a year.

The identification of sensitive areas was based on bird and bat observation data, information on 559 Natura 2000 sites and 11 regional waste disposal sites that attract gulls, storks and other sensitive bird species. Actual bird (10,360 points and 1,103 polygons) and bat (7,138 points and 45 polygons) data were collected between 2015 and 2017 (VENBIS database). An additional 3,718 point observations were collected during 2010–2016, and were sourced from The MoE Information System of the Protected Species of Lithuania. Further surveys were commissioned for municipalities where historical data were unavailable or little research had been previously conducted.

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (2/8)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds and bats
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public
Format	Static maps, interactive ArcGIS online platform.
Data sources	Species occurrence records, habitat maps, expert consultation.
Factors contributing to the calculation of sensitivity	Proportion of regional population, proportion of national population. Global conservation status (e.g. IUCN Red List), national conservation status, EU conservation status (Nature Directives). Species behaviour (flight height, degree of wariness etc.), migratory behaviour (timing, routes etc.). Habitat sensitivity in terms of Natura 2000 sites
Intended data update cycle	Desired but not planned
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (3/8)

Sensitivity scores for breeding and migratory bird species were attributed through consultation with experts including from the Lithuanian Ornithological Society (BirdLife in Lithuania). For bat species, the sensitivity scores were based on information about flight heights, foraging behaviour and known susceptibility for collision, which were extracted from Rodrigues *et al*. 2008.

Analytical approach

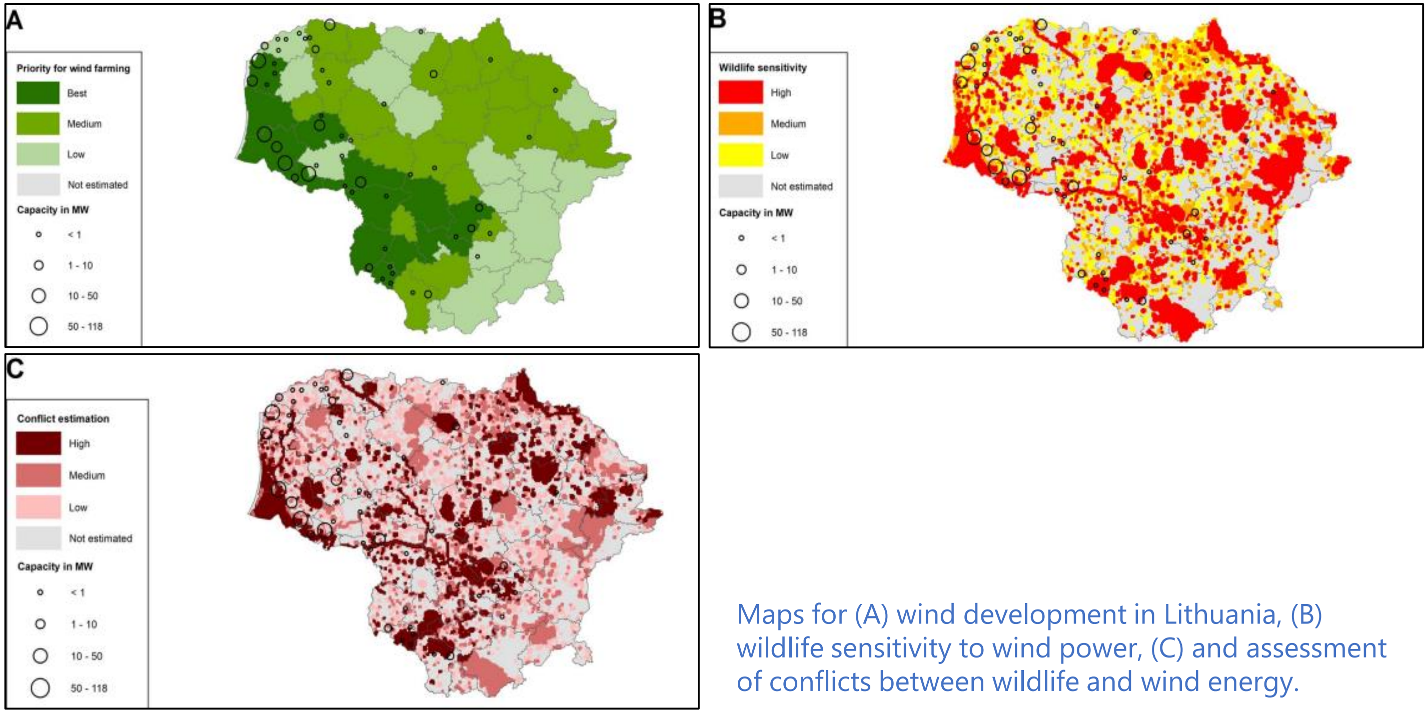
An integrated assessment of wind energy development and wildlife sensitivity was performed using a sequence of procedures. As a first step, an assessment of the perspectives of wind energy development was undertaken and complemented by wind resource modelling and local area parameters. The second step was the wildlife sensitivity assessment by using species traits and the importance of areas for birds and bats. The final assessment of conflict between the perspectives for wind development and wildlife sensitivity was based on a simple matrix to estimate the likelihood of conflict in particular scenarios. This matrix informed the output of the final maps and the percentages of high, medium and low conflict zones were calculated for each municipality.

The wind resources were described by the mean wind power density at a height of 50 m, which was derived from wind measurement data at hourly intervals from meteorological stations over a single year (2016). Measurements made at a height of 10m were converted to 50m with consideration of topography and surface roughness length based on aerial photos of the areas surrounding meteorological stations. Where municipalities lacked wind data, values were used from neighbouring municipalities. Weibull distribution parameters were used to assess mean power density at 50m, calculated using the Maximum Likelihood Estimate (MLE) method using WindPRO 3.0 and WAsP 9 software.

Five factors were considered for assessing the prospects of wind energy development in each municipality. These included: (A) wind energy resource (range 60-342 W/m2), (B) grid connectivity, (C) existing 'special plans' for fast-tracking wind energy development, (D) forecast expansion of wind (range 0 - 213MW), and (E) the percentage of forest (range 11 - 69%). Each factor was ascribed a value of 1-3 and a weighting according to the formula:

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (4/8)



Maps for (A) wind development in Lithuania, (B) wildlife sensitivity to wind power, (C) and assessment of conflicts between wildlife and wind energy.

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (5/8)

I = A × 0.35 + B × 0.25 + C × 0.20 + D × 0.10 - E × 0.10

The results of the calculation were placed into three priority groups according to the sum of points, where higher numbers represent more favourable conditions for wind energy deployment.

Bird and bat maps were based on the distribution of a selection of 69 breeding and 43 migratory bird species and all 17 bat species in Lithuania. Sensitivity was determined on the species' vulnerability to the effects of wind farm development and operation, and on their national and international conservation status.

Overall sensitivity scores (A) were estimated as:

$$A = D \times (B+C)$$

Where (B) - a conservation score based on national importance of birds and bats and international importance (for birds only)

(C) - species sensitivity to the possible effects of wind energy development,

(D for birds) - local relative abundance of birds compared to countywide abundance and

(D for bats) - the number of bat species at 1km observation squares.

(See table depicting sensitivity scoring for birds and bats - scores range between 1-3 and are shown in brackets).

Buffer zones varying from 500m to 2km were selected for 71 bird and 16 habitat areas. All breeding locations for bat species had buffer zones of 1km and all wintering locations for bird species gained buffers of 2km. Additionally, flight corridors and waste disposal sites were considered high sensitivity and gained a buffer of 2km. Natura 2000 sites in Lithuania designated for the protection of birds (84) and habitats (475) and were automatically considered as highly sensitive.

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (6/8)

Parameter		Birds – Breeders	Birds – Migrants	Bats
A	Overall sensitivity score	(High) >12		(High) >20
		(Medium) between 7 and 12		(Medium) between 9 and 20
		(Low/ unknown) between 1 and 6		(Low/ unknown) between 2 and 8
B	Conservation score	{3)-categories of O (Extinct) or 1 (Endangered) in LRB and CR or EN in IUCN		{3) - 0 or 1 in LRB
		(2)-categories of 2 (Vulnerable) or 3 (Rare) in LRB and VU or NT in IUCN		(2) - 2 or 3 in LRB
		{1)-categories of 4 (Intermediate) or 5 (Restored) in LRB and LC in IUCN		{1) - 4 or 5 in LRB
C	Sensitivity to wind energy development	(2)-high		{3)-high
		(1)-medium		(2)-medium
		(O)-low		{1)-low/ unknown
D	Local relative abundance	(3) >0.5% of overall country population	{3) observed abundance is higher than significant number for a species	Number of bat species at 1-km square resolution, which was based on actual observations
		(2) between 0.5%-0.1% of overall country population	(2) observed abundance is between minimal and significant number of individuals	
		(1) <0.1 % of overall country population	(1) observed abundance is lower than minimal number of individuals	

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (7/8)

The sensitivity maps were produced on ArcGIS using a 1km^2 grid. Four main maps were produced for breeding birds, migratory and wintering birds, bats, and Natura 2000 sites and waste disposal sites. The full maps and details of their generation of are available as GIS layers through VENBIS website. Each map has layers that can be switched on and off and depict four sensitivity categories from highly sensitivity areas, moderately sensitivity areas, low sensitivity areas and not enough data to determine sensitivity. The full report for generation of the maps is only available in Lithuanian.

Uptake

The project was a collaborative approach between the Lithuanian Ornithological Society, the Coastal Research and Planning Institute, the Lithuanian Energy Institute, EEA Grants and Norway Grants and the Ministry of Environment of the Republic of Lithuania. This highly participatory approach will increase the likelihood of a successful project legacy, as well as uptake by the energy industry and recognition by the government.

This project is expected to guide all future developments through informing EIA assessments and its use is recommended by the Ministry of Environment.. During the VENBIS project, recommendations on appropriate methodologies for monitoring birds and bats at wind farms were produced and disseminated. These have improved the quality of EIAs and wildlife monitoring before and after wind farm installations in Lithuania.

Effectiveness

Whilst wind energy resource was assessed for the entire country, wildlife sensitivity was only assessed for 64% of Lithuania due to limited data for the remaining 36%. Consequently, the areas of potential conflict could only be assessed where there were estimations of wildlife sensitivity. Of the area studied, 32% of Lithuania was estimated as high sensitivity with 19% medium sensitivity, although these numbers are likely to be significantly higher if more of the country is assessed. The ability of the maps to produce a more accurate estimation of sensitivity across the country would be enhanced with more data on wildlife occurrence. The map served well to identify high sensitivity areas, such as the Curonian Lagoon, Varėna, Biržai and

Examples of wildlife sensitivity mapping

Lithuanian sensitivity map for birds and bats in relation to onshore wind (8/8)

Anykščiai.

The study highlighted that 73.2% of installed capacity (>350 kW) was located in first priority zones, while 14.4% and 12.4% of wind power was installed in second and third priority zones for wind power. This demonstrated that without adequate consideration of wildlife national wind planning is likely to continue to create potential conflicts with wildlife.

This was an extremely well documented project with full reports for all the stages of the project, including field research, located on the VENBIS project website. These reports are in Lithuanian, but will facilitate any future replication or update to this project.

Adaptability
The project already recognises and makes up for some of the shortcomings of other sensitivity mapping projects, in terms of limited species assessments, lack of industry specific data, and a focus on just species of conservation concern. However, the map is adaptable due to its simple and replicable methodology. For example, similar methods could be rolled out in other Baltic countries, subject to data availability. The GIS platform also makes it possible for future updates and modifications to be easily rolled out on the same platform. The lack of marine data and high wind resource on the coast suggests that a potential option for future updates would be to include marine birds and marine mammals in the tool.

References

Morkūnė, R., Marčiukaitis, M., Jurkin, V., Gecevičius, G., Morkūnas, J., Raudonikis, L., Markevičius, A., Narščius, A. and Gasiūnaitė, Z.R. (2020). Wind energy development and wildlife conservation in Lithuania: A mapping tool for conflict assessment. *Plos one*, 15(1), p.e0227735.

Rodrigues L, Bach L, Dubourg-Savage M-J, Goodwin J, Harbusch C. (2008). *Guidelines for consideration of bats in wind farm projects. UNEP/EUROBATS* Secretariat, Bonn, Germany: EUROBATS Publication Series No. 3 (English version); p.51.

Examples of wildlife sensitivity mapping

The Netherlands national wind farm sensitivity map (1/4)

Commissioned by Vogelbescherming Nederland (VBN). Developed by Altenburg and Wymenga Ecological Consultants and SOVON bird research.

Summary
Avian sensitivity maps for the Netherlands were primarily developed with the intention of making the Society for the Protection of Birds (VBN) conservation policy 'spatially explicit', and to harmonize the discussions regarding onshore wind farm development with other conservation NGOs. It further evolved as a spatial mapping tool for the early screening of wind farm developments. The tool focusses on terrestrial bird populations, and includes sites of ornithological importance such as migration hotspots, high nature value farmland and important roosting sites.

Data
All land birds were included, and data were compiled from a variety of sources, including the national breeding bird census, waterbird counts, colonial bird counts, data from a bird airstrike model (BAMBAS; bird biomass of flying birds), Natura 2000 sites, and specific rare bird inventories. Migration hotspots were also integrated. Risk maps were generated for overall risk across all layers, as well as for the individual layers used to compile the map.

Analytical approach
For each 'layer' of the map, the grid cells in the Netherlands were classified as being of low, moderate or high value based on the importance of the site and/ or species. Buffer zones were identified for each species and applied to the maps. The scores form the various grid cells were aggregated in the final map.

Additional features
NA

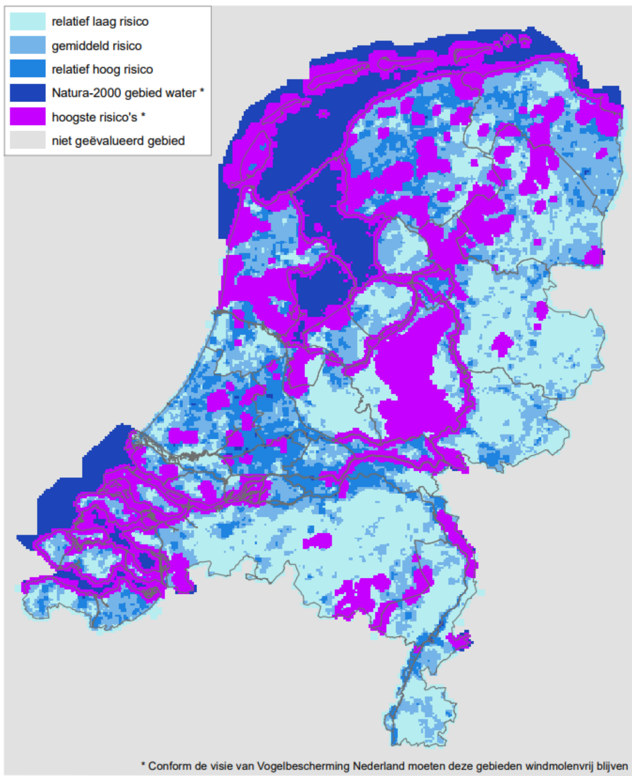
Examples of wildlife sensitivity mapping

The Netherlands national wind farm sensitivity map (2/4)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Seabirds, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Phasianidae (pheasants), Apodidae (swifts), Passerines
Intended users	Planning authorities, Government agencies, Conservation NGOs, General public
Access	Public
Format	Static maps
Data sources	Species range maps, Species records, Migration routes, Conservation sites
Factors contributing to the calculation of sensitivity	Proportion of national population, Global conservation status (e.g. IUCN Red List), National conservation status, EU conservation status (Nature directives)
Intended data update cycle	Not planned
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	81-100%

Examples of wildlife sensitivity mapping

The Netherlands national wind farm sensitivity map (3/4)



Overall risk-map illustrating risk from highest (purple) to relatively low risk (light blue) (Source: Aarts and Bruinzeel 2009)

Examples of wildlife sensitivity mapping

The Netherlands national wind farm sensitivity map (4/4)

Uptake
While not formerly adopted within the Dutch planning system, the map is widely used. It remains the only wind turbine risk map in the Netherlands. Since its development in 2009 it is estimated that it has been used at least 100 times.

Effectiveness
The tool is available as a standalone report, which includes all maps and the background information and methodology. The maps are clear and with the availability of the individual layers also it is relatively easy to determine which species are influencing the risk in a particular area. This is a simple tool that has compiled bird records from a variety of sources to identify a risk map that defines the highest bird sensitivity areas across the Netherlands and has proved very useful as a screening tool.

Adaptability
The approach used to develop this tool could be extended spatially, as well as to include other taxa. However, it would be recommended with increasing layers to integrate some measure of collision risk to enable refinement of the final map.

References
Aarts, B. and Bruinzeel, L. (2009) *De nationale windmolenrisicokaart voor vogels*. SOVON Vogelonderzoek Nederland/Altenburg & Wymenga

Examples of wildlife sensitivity mapping

Smart Wind Chart evaluation tool for offshore wind in the Mediterranean and Black Seas (1/4)

The CoCoNET project was coordinated by CNR-ISMAR involving 39 partners from 22 countries

Summary
The FP7 CoCoNet project included an assessment of the integration between offshore wind farms and Marine Protected Areas (MPAs). This was delivered in four main steps: (i) the identification of existing MPAs focusing on biodiversity distribution patterns and current legislation, (ii) the coupling of offshore wind potential within networks of MPAs, (iii) the evaluation of the knowledge gained up to date and the theoretical approaches at the two pilot sites of the Mediterranean and Black sea basins, and (iv) the development of the "Smart Wind Chart", a convenient and rational tool addressed to scientists and policy makers for the evaluation of maritime policy management schemes.

The Smart Wind Chart aims to maintain and secure the sustainable 'blue' growth in the Mediterranean and Black Seas through the support of offshore wind energy projects and marine habitat conservation.

Data
The tool is based on a combination of factors influencing the siting of wind farms such as wind and bathymetry data, and on constraints, including socio-economic and environmental datasets. The data for all the environmental variables were derived from the "Mediterranean Sensitive Habitat" (MEDISEH) project (see http://mareaproject.net/). Environmental datasets included protected sites, Ramsar sites, MPAs, Natura 2000, bird migration routes, areas characterised by *Posidonia oceanica* or *Phyllophora crispa*), biogenic habitats, deep sea coral formations. Other spatial datasets included military areas, port entrances, shipping routes, archaeological sites, oil and gas extraction, aviation, aquaculture and fishing.

Examples of wildlife sensitivity mapping

Smart Wind Chart evaluation tool for offshore wind in the Mediterranean and Black Seas (2/4)

Geographic scope	Multi-national
Renewable energy sector	Offshore wind
Taxonomic focus	Cetacea (whales, dolphins, porpoises), Birds, Habitats, coral
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Partially restricted
Format	Static map and GIS shapefile
Data sources	Species records, Habitat maps, Conservation sites, Topography, Resource maps
Factors contributing to the calculation of sensitivity	Protected areas
Intended data update cycle	Not planned
Use in planning process	Not currently used
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

Smart Wind Chart evaluation tool for offshore wind in the Mediterranean and Black Seas (3/4)

Analytical approach

The Smart Wind Chart is a flexible tool for the comparison and evaluation of the potential offshore wind farm locations according to some quantifiable multi-parameter eligibility criteria. It was developed through the following stages:

1. Identify and liaise with key stakeholders
2. Preparatory phase included:
   a. Assessment of criteria, factor rating table.
   b. Identification of no-go/ restricted areas (mainly due to environmental considerations).
   c. Technical criteria – wind speed, depth, also distance to shore, proximity to ports, electrical grid infrastructure, bottom sediments. These factors rated from 1 (least feasible) to 5 (most feasible) and were then assigned a weight reflecting the relative importance in offshore wind farm development.
   d. The overall score at each location was estimated as a combination of factor ratings and relative weights.
   e. No-go/restricted areas were decided primarily on environmental grounds, especially areas characterised by coralligenous formations, *maerls, P. oceanica/ P. crispa*. The other protected sites, MPAs, Natura 2000 sites etc. were reviewed, and restrictions decided based on biological, ecological and conservation importance.
3. Processing phase:
   a. Important parameters considered include mean annual wind speed and bottom depth.
   b. The resulting "potentially go" areas were then graded according to the other factors mentioned above.

Additional features

The platform is stable across all web interfaces and enables interrogation of all of the individual layers that were used to develop the Smart Wind Chart. The website provides good backing details and data download facilities. However, the tool is quite slow to navigate, presumably because of the size and number of layers that it integrates.

Uptake

Use of the tool is not mandatory, and its uptake and usage is unknown.

Examples of wildlife sensitivity mapping

Smart Wind Chart evaluation tool for offshore wind in the Mediterranean and Black Seas (4/4)

Effectiveness

It was stipulated that the locations evaluated through this tool should not be considered as direct suggestions for future offshore wind farm development, but merely as favourable candidate areas that require further in-depth assessment in the context of detailed feasibility studies.

Adaptability

The method adopted is straightforward and could be extended to other areas and/ or to include other taxa as they become available.

The method adopted for the development of the SWC includes all of the key elements, such as stakeholder liaisons, and the integration of factors that are affected by wind farm development. This tool is focussed on appropriate siting of wind farms, so it screens out areas unsuitable in the first instance (due to unsuitable wind speeds and sea depths), so does not provide sensitivity for the entire region. Furthermore, the sensitivity is entirely based on conservation/ ecological value and does not include factors that relate to impact.

References

Soukissian, T., Reizopoulou, S., Drakopoulou, P., *et al*. (2016) Greening offshore wind with the smart wind chart evaluation tool. *Web Ecology* 16: 73–80.

Examples of wildlife sensitivity mapping

Avian wind farm sensitivity map for South Africa (1/6)

BirdLife South Africa in partnership with the Endangered Wildlife Trust

Summary
BirdLife South Africa and the Endangered Wildlife Trust developed the Avian Wind Farm Sensitivity Map for South Africa in 2011. It is designed to assist planners and wind farm developers in minimising the negative impacts of wind energy infrastructure on birds. The map was based on existing data (e.g. the South Africa Bird Atlas Project data, collected by citizen scientists). The map is used to give an early indication of species likely to be at risk in the area, but confidence in the output is not evenly distributed throughout the country due to incomplete and uneven data coverage. The map is now outdated, and a significant revision is required to better align with the national planning process and stakeholder needs.

Data
The mapping project took into account currently planned wind development projects but many areas prioritised for wind energy are poorly represented in the Atlas due to their remoteness.

Although data for this map were acquired at a relatively course scale, most wind farms span multiple pentad squares (5 min latitude x 5 min longitude) and the correct sensitivity for a site should have been captured. These pentads are useful as they facilitate the mapping process and compiling data layers, but they are not a meaningful biological unit. The data was free to obtain as it was collected by citizen scientists and national organisations. However, this type of data has the limitation of incomplete and uneven geographic coverage. Although the data represented actual records, it was outdated in some areas and whilst a confidence factor was included, lack of data could be misinterpreted as low sensitivity. Furthermore, the map was developed in the absence of any data on actual impacts on birds in South Africa, thus prioritisation of species may have been

Examples of wildlife sensitivity mapping

Avian wind farm sensitivity map for South Africa (2/6)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Seabirds, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Phasianidae (pheasants), Otididae (bustards), Apodidae (swifts), Passerines, Other- Cranes; Sandgrouse; Secretarybird; Flamingos
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public
Format	GIS shapefile, Google Earth layer
Data sources	Species records, Habitat maps, Conservation sites , Infrastructure maps - existing wind farms
Factors contributing to the calculation of sensitivity	Endemism/near endemism and range size, Global conservation status (e.g. IUCN Red List), Regional conservation status, Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Displacement and collision vulnerability
Intended data update cycle	Hopefully in future
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

Avian wind farm sensitivity map for South Africa (3/6)

incorrect. It is important to ensure that the map does not replace or delay stakeholder engagement where better data (e.g. up-to-date, fine-scale, confidential and/or information on cumulative impacts) could have been made be available.

Analytical approach

The map made the best use of available data nationwide and was combined with expert opinion in areas such as assessing species sensitivity. Because atlas data is constantly updated, the process could be repeated and updated which would lead to up-to-date estimations.

Analysis took into account both collision risk and sensitivity to disturbance for species but sensitivity was calculated on presence-absence data rather than the relative importance of an area for a species. The large number of species (105) considered in the sensitivity analysis complicated the output and interpretation. It may have been better to focus on the most critical features that could drive selection of sensitive sites for birds.

The size of populations potentially affected by development was not taken into account. Additionally, topography and other features associated with increased collision risk were not taken into account.

Additional features

The map is available online but interpreting drivers of sensitivity was not particularly easy. It is possible (although not simple) to access a list of priority species recorded in the area of interest. Therefore, accessibility and interactivity for map users could be improved, as well as presenting more information in the final maps. The map could be potentially misinterpreted if not considered in consultation with experts. Therefore, ease of access will be important in future versions. As would flagging very high-risk areas.

Uptake

The tool is well known amongst relevant stakeholders, especially avifaunal specialist consultants and was widely disseminated by the South African Wind Energy Association. However, the end product could not be easily aligned to the approaches used in

Examples of wildlife sensitivity mapping

Avian wind farm sensitivity map for South Africa (4/6)

the national SEA (in terms of scale of data, mapping units and sensitivity classes). It is difficult to determine the extent of use by developers, planners and other stakeholders.

Effectiveness

The map provided a good summary of the available information, based on actual records for those species likely to be vulnerable to onshore wind energy facilities. The prioritisation of species proved to be a key element of the project and helps focus planning, EIAs, monitoring, mitigation and research. Cumulative impacts would be a good additional feature to include in order to make the tool more powerful.

The Strategic Environmental Assessment Process for Wind and Solar Energy (SEA) is a government led initiative. The approach classifies a particular theme (e.g. birds, bats, agriculture, aquatic biodiversity etc.) into four sensitivity classes (low, medium, high and very high). The wind farm sensitivity map was not designed explicitly with this approach in mind. Because of the large number of species considered in the sensitivity map scoring, there was a considerable range in overall scores for pentad squares, which made identifying appropriate thresholds for different categories difficult. Furthermore, confidence in the output of the sensitivity map was not high, as inconsistent survey effort also meant that in some areas with low sensitivity were actually just poorly surveyed and the use of pentads was not well-received as the boundaries between classes did not relate to features on the ground. As a result, the sensitivity map was not included in the SEA.

However, one of the more useful outputs of the sensitivity mapping project was the prioritisation of species, and this information was used by the consulting ornithologist for the SEA, who considered locations or habitats important for a shortlist of these birds in the assessment of "focus areas" of the SEA.

The map developers intend to update the map and hopefully address some of these shortcomings. For example, improving the data in areas where the map was previously ineffective due to limited species records. This would help to ensure that development is not inadvertently steered in the direction of

Examples of wildlife sensitivity mapping

Avian wind farm sensitivity map for South Africa (5/6)

remote, poorly surveyed areas (if confidence factor not taken into account). Currently, the government is developing a site screening tool (for all developments that require EIA) that will use the same four categories as the sensitivity classes (low, medium, high and very high). The aim of future sensitivity mapping products is to align these with government approaches to enhance compatibility.

Adaptability

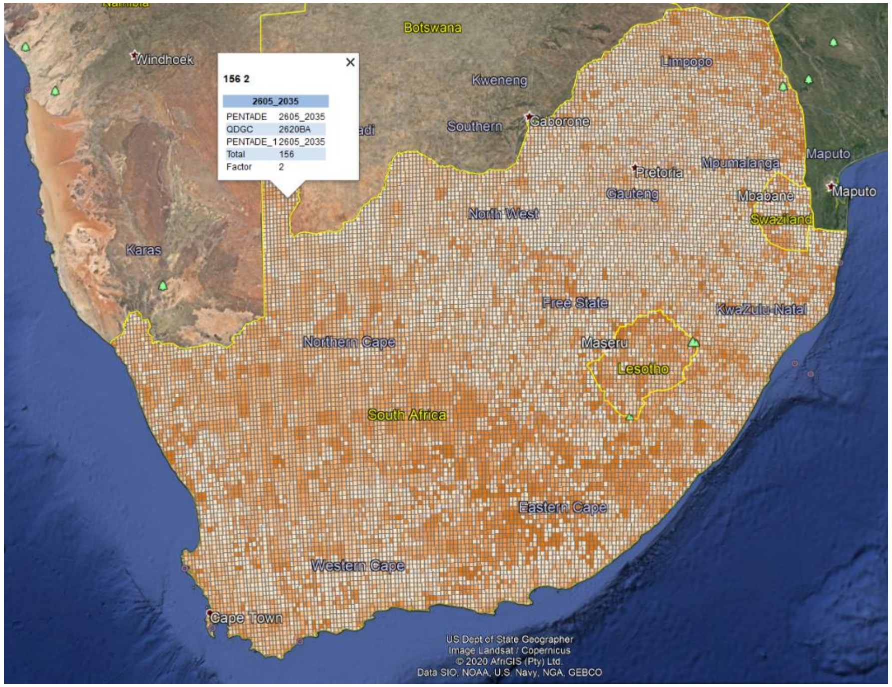
The map relies upon existing South African Bird Atlas Project data. Additional information could be added and where similar data is available for other taxa, the scale of data units would need to be considered—it might not always be appropriate. It would be possible to adapt this map for other taxa and in other countries where atlas data (or similar) is available. Freely attainable data, such as high quality or filtered citizen science data may be appropriate for an equivalent version of this map in other contexts.

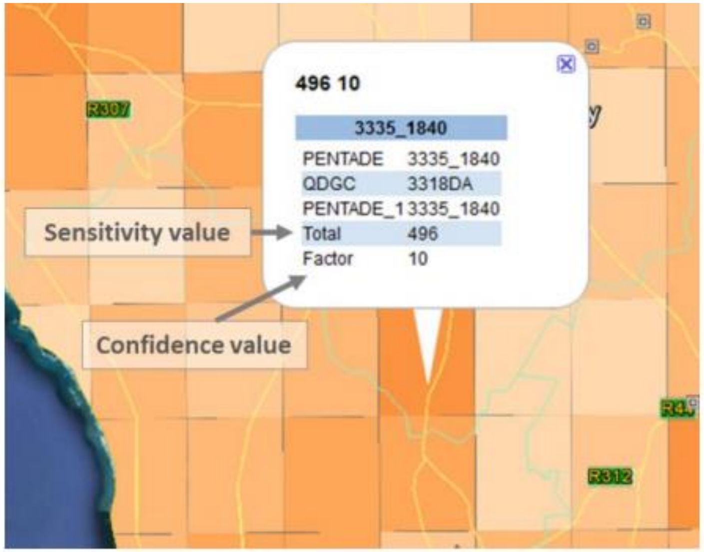
This map considered a potential overlap of new development with proposed wind energy facilities when prioritising species for their sensitivities. It is important to consider a dynamic system as the current renewable development in the country could change quickly with energy expansion resulting from such as improved technology and government incentives.

As one of the few examples of sensitivity mapping outside Europe, this map provides an opportunity to understand how these techniques apply to different habitats and species. It provides a good assessment of sensitivity whilst considering planned projects and acknowledging the shortcomings of the data.

Examples of wildlife sensitivity mapping

Avian wind farm sensitivity map for South Africa (6/6)





A Google Earth view of the sensitivity map indicating where to find the sensitivity and confidence values.

Examples of wildlife sensitivity mapping

Wind energy sensitivity mapping in Germany (1/5)

WWF Germany, Bosch & Partner

Summary

This study adopts a bottom-up approach to examine the impact of onshore wind energy on the habitats of vulnerable bird species in six districts in Brandenburg, Saxony-Anhalt and Rhineland-Palatinate. The study identifies 20 ‘exclusion’ categories (some of them non-conservation) which were used to exclude non-suitable areas. The remaining areas were evaluated by using 25 ‘restriction area’ categories (also some of them non-conservation) to determine areas of potential risk. The restriction categories included nature conservation sites, and the distributions of bird species considered to be vulnerable to development. These were based on known distributions combined with modelled distributions based on habitat data (Corine Land Cover). Additional density information relating to three species, namely Red Kite *Milvus milvus*, Eurasian Buzzard *Buteo buteo* and Northern Lapwing *Vanellus vanellus*, were also included.

Data

The analyses incorporated a wide variety of factors, including those related to the legal restrictions governing wind development, such as proximity to infrastructure and residential areas etc. The following nature conservation datasets were included in these analyses:

- Protected areas (nature reserves, biosphere zones, national parks, SPAs etc.).
- Data from the Atlas German breeding birds (ADEBAR, Gedeon *et al*. 2014).
- Project type-specific mortality hazard index (VMGI, Bernotat & Dierschke 2016).
- Corine Land Cover (CLC 2012).
- Allocation of CLC for breeding season habitat (breeding and feeding habitat during the breeding season) for a selection of wind energy sensitive birds.

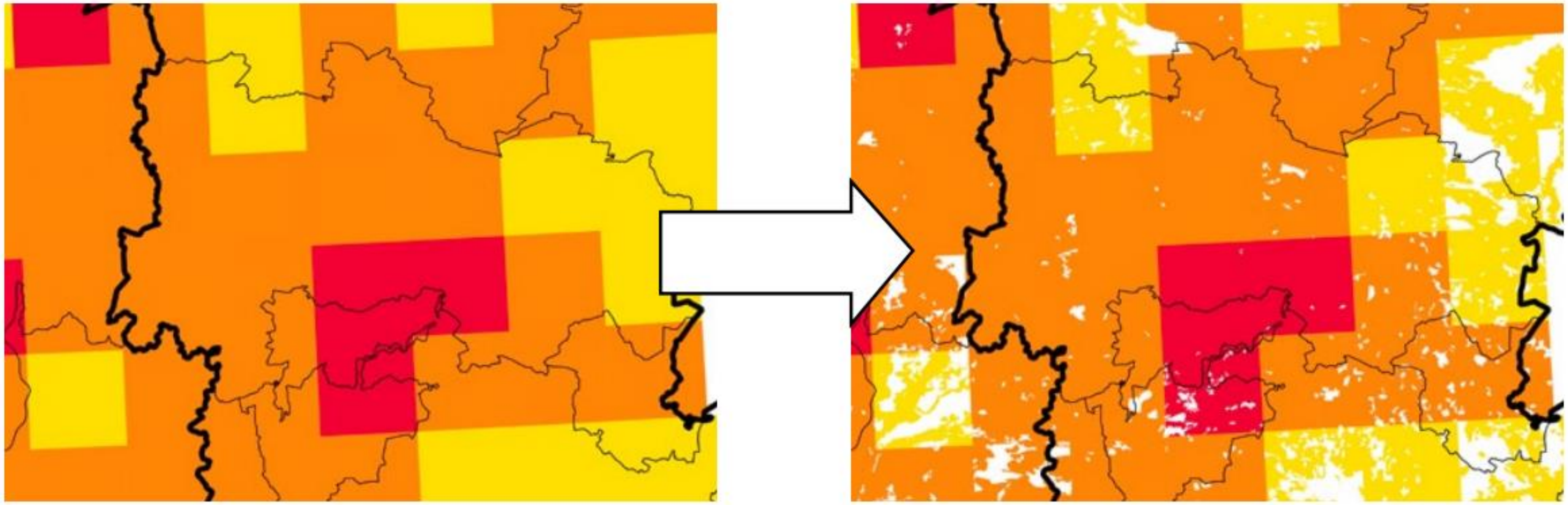
Examples of wildlife sensitivity mapping

Wind energy sensitivity mapping in Germany (2/5)

Geographic scope	Regional
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Seabirds, Waders (Lapwing), Anseriformes
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Fully restricted
Format	Static maps in reports
Data sources	Species records, Habitat maps, Conservation sites , Topography, Infrastructure maps
Factors contributing to the calculation of sensitivity	Proportion of global population, Proportion of regional population, Global conservation status (e.g. IUCN Red List) Regional conservation status, National conservation status, EU conservation status (Nature directives), Habitat Sensitivity
Intended data update cycle	To be decided
Use in planning process	No
Percentage of siting decisions in which the tool is utilised	None yet

Examples of wildlife sensitivity mapping

Wind energy sensitivity mapping in Germany (3/5)



Extract from the map showing refinements made based upon breeding season habitat within grid squares (derived from CLC) and wind farm related risks (Busch *et al.* 2017).

Examples of wildlife sensitivity mapping

Wind energy sensitivity mapping in Germany (4/5)

Analytical approach
A consultation process was undertaken with experts to identify those factors associated with wind energy development that affect nature conservation. There is a list of 20 exclusion categories (some of them non-conservation) that were used to exclude non-suitable areas. The remaining areas were evaluated by using 25 restriction area categories (also some of them non-conservation) to determine areas of potential risk. All relevant layers were overlaid using GIS and the highest identified risk value was assigned to every cell of a 25 x 25 m result grid.

Nature protection sites were included (among the other 25 restriction categories) and were scored in accordance to their potential risks of conflicts between wind energy and nature conservation. Furthermore, the conservation areas were scored based on their level of protection and the presence of vulnerable species in the protection site.

There was a basic analysis of 41 vulnerable bird species and vulnerability and distributions were extracted from ADEBAR. CLC data were used to identify potential habitats for all vulnerable species and these were scored in relation to their vulnerability. The 2012 dataset provided land cover information at a geographic accuracy of 25 ha minimum mapping units and 100 m minimum mapping width.

Red Kite *Milvus milvus*, Eurasian Buzzard *Buteo buteo* and Northern Lapwing *Vanellus vanellus* were analysed in greater detail. CLC data were used to identify potential habitats for the three species, and a measure of density (the number of individuals per habitat) was also integrated and calculated based on more detailed distribution data from ADEBAR. The results were used to determine the regional impact of wind energy development scenarios on these species.

Uptake
The tool is available only as a report. It was not developed with government support and has not been formally adopted within the planning system. Currently, uptake is unknown.

Effectiveness
It is too early to determine the impact of this report.

Examples of wildlife sensitivity mapping

Wind energy sensitivity mapping in Germany (5/5)

Adaptability
The approach used is broadly similar to others where the primary objective has been towards determining appropriate siting of wind farms.

References

Bernotat, D. and Dierschke, V. (2016) *Übergeordnete Kriterien zur Bewertung der Mortalität wildlebender Tiere im Rahmen von Projekten und Eingriffen – 3*. Fassung – Stand 20.09.2016, 460 Seiten.

Busch, M., Trautmann, S. and Gerlach, B. (2017) Overlap between breeding season distribution and wind farm risks: a spatial approach. *Vogelwelt*, 137: 169-180.

Gedeon, K., C. Grüneberg, A. Mitschke, C. Sudfeldt, W. Eickhorst, S. Fischer, M. Flade, S. Frick, I. Geiersberger, B. Koop, Bernd, M. Kramer, T. Krüger, N. Roth, T. Ryslavy, S. Stübing, S. R. Sudmann, R. Steffens, F. Vökler and K. Witt (2014): *Atlas Deutscher Brutvogelarten – Atlas of German Breeding Birds*. Herausgegeben von der Stiftung Vogelmonitoring und dem Dachverband Deutscher Avifaunisten. Münster.

Regionale Auswirkungen des Windenergieausbaus auf die Vogelwelt. Eine exemplarische Untersuchung von sechs bundesdeutschen Landkreisen.

Examples of wildlife sensitivity mapping

Seabird sensitivity mapping for offshore marine renewable energy developments in Ireland (1/4)

BirdWatch Ireland. Funded by SEAI, NTR, EIRGRID and ESB.

Summary

BirdWatch Ireland's Sensitivity Mapping for Offshore Marine Renewable Energy Developments in Ireland is currently being development in three phases. Phase 1 was a scoping study that explored the feasibility of developing sensitivity maps across three renewable energy development types (offshore wind, Wave, tidal). Species sensitivity scores were assigned to each species based on their conservation status and their vulnerability to each of wind, wave and tidal devices. The second phase trialled the development of a map, at a regional scale (east coast) for a selection of species. A stakeholder workshop was held following the second phase, which highlighted that there is support and demand for a wider sensitivity mapping development for Irish waters across all species. This is now in development.

Data

A variety of data sources were used to develop this tool:

- The primary source was from boat-based seabird surveys. The European Seabirds at Sea (ESAS) database is a shared database containing results of ship-based and aerial seabird surveys from different sources in northwest European waters, since 1979.
- Data from four wind energy projects, in various stages of the planning, consenting and development processes, were made available by the respective developers.
- Two studies that modelled breeding seabird foraging distributions based on recent high-resolution GPS tracking projects also made their data and results available for this project.
- Northern Gannet *Morus bassanus* tracking projects at Irish colonies were contributed to the study by Wakefield *et al.* (2013), and similar efforts on European Shag *Gulosus*

Examples of wildlife sensitivity mapping

Seabird sensitivity mapping for offshore marine renewable energy developments in Ireland (2/4)

Geographic scope	National
Renewable energy sector	Offshore wind, Wave/tidal
Taxonomic focus	Seabirds Anseriformes (ducks, geese, swans)
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Fully restricted
Format	GIS shapefile
Data sources	Species range maps, Species records
Factors contributing to the calculation of sensitivity	Proportion of global population, Global conservation status (e.g. IUCN Red List), National conservation status, EU conservation status (Nature directives), Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.)
Intended data update cycle	To be decided - dependent on funding and new data
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	Still under development

Examples of wildlife sensitivity mapping

Seabird sensitivity mapping for offshore marine renewable energy developments in Ireland (3/4)

aristotelis, Black-legged Kittiwake *Rissa tridactyla*, Razorbill *Alca torda* and Common Murre *Uria aalge* allowed Wakefield *et al.* (2017) to predict regional seabird distribution by also incorporating habitat information.

- Data from the Irish Wetland Bird Survey (I-WeBS) were included, but are restricted to observations from the coast and do not reflect the extent of offshore areas used by wintering birds.
- The Marine Institute commissioned aerial surveys in the Irish Sea in 2014, which gave particular focus to Common Scoter *Melanitta nigra*, thus providing additional information on the target species for which we are most data-deficient at present.

Analytical approach

All seabird species (including wintering seaducks, divers and grebes) were included in the initial review, and the sensitivity scores for each of wind collision, wind disturbance, tidal and wave energy developments calculated as follows:

1. A Risk Collision Score (RCS) relating to wind energy was calculated as Flight altitude x (Flight manoeuvrability + Percentage of time flying + Nocturnal flight activity)/3 x Conservation Importance score
2. A Disturbance Score (DS) relating to wind was calculated as ((Disturbance by wind farm structures, ship and helicopter x Habitat specialisation) x Conservation Score)/10.
3. Tidal Score = (Tidal race x Diving depth x (Drowning risk + Benthic foraging + Feeding range + Disturbance by ship traffic + Habitat specialization)/5 x Conservation score)/100
4. Wave Score = the sum of the seven factors that could describe the vulnerability of birds to wave devices multiplied by their conservation score. These wave factors included adverse effects (risk of collision mortality, exclusion from foraging habitat, disturbance by structure, disturbance by ship traffic and habitat specialisation) and positive benefits (roost provision, fish attraction and biofouling).

Trial maps for each development type were developed based on a selection of six species, these focussed on the Irish Sea, and

Examples of wildlife sensitivity mapping

Seabird sensitivity mapping for offshore marine renewable energy developments in Ireland (4/4)

were applied to a 4 x 4 km grid.

Additional features
NA

Uptake
The tool is currently under development.

Effectiveness
The tool is currently under development but promises to be an effective marine sensitivity mapping tools due to its considerations of wave and tidal energies in additional to offshore wind.

Adaptability
The tool is currently under development.

References

Burke, B. (2018) *Trialling a Seabird Sensitivity Mapping Tool for Marine Renewable Energy Developments in Ireland*. BirdWatch Ireland, Kilcoole, Co. Wicklow.

Ramiro, B. and Cummins, S. (2016) Feasibility study of Marine Birds Sensitivity Mapping for Offshore Marine Renewable Energy Developments in Ireland. Unpublished BirdWatch Ireland report. Kilcoole, Co. Wicklow.

Examples of wildlife sensitivity mapping

Site Wind Right (Low-impact Wind Mapping Tool) (1/5)

The Nature Conservancy

Summary

To support a more rapid transition to low-carbon energy, whilst protecting iconic landscapes and species, The Nature Conservancy has identified low-risk areas for wind development across the central U.S. The project represents the most extensive wind energy sensitivity mapping in North America to date. It has developed from a number of initial studies, such as Obermeyer *et al*. (2011). By combining maps of sensitive natural habitats with wind speed and land use information, it has been demonstrated that 1,000 GW of wind energy may be developed in the central U.S. exclusively in areas of low conservation impact. In Kansas and Oklahoma alone, these low-risk areas have the potential to yield approximately 190 GW of electrical capacity, more than 20 times greater than ambitious development projections for the region.

Data

The interactive online map uses GIS technology and incorporates more than 100 data sets on wind resources, wildlife habitat, current land use and infrastructure. Some of the taxa covered and techniques employed (e.g. beetles and playa wetlands, Next Generation Weather Radar stations and special use airspace) have not been considered in previous wildlife sensitivity mapping approaches.

The map utilises databases on engineering constraints and existing wind farms. It considered a large range of factors, such as viable wind speeds and slopes that are too steep for development. However, with certain species in the region, the potential impacts from wind development, as well as the operation of existing facilities, is poorly known and further data is required to improve understanding.

Examples of wildlife sensitivity mapping

Site Wind Right (Low-impact Wind Mapping Tool) (2/5)

Geographic scope	Regional
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of prey, Anseriformes (ducks, geese, swans), Phasianidae (pheasants), Bats, Insects (Burying beetles), Other threatened and endangered species including plants
Intended users	Planning authorities, General public
Access	Public
Format	Mapping Interface, Static maps, GIS layers
Data sources	Species range maps, Species records, Habitat maps, Migration routes, Conservation sites, Topography, Resource maps, Infrastructure maps
Factors contributing to the calculation of sensitivity	Proportion of global population, Proportion of global population, Proportion of national population, Regional conservation status, National conservation status, Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.)
Intended data update cycle	Annually
Use in planning process	Map not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

Site Wind Right (Low-impact Wind Mapping Tool) (3/5)

Analytical approach
The map predominantly utilises knowledge of important areas for certain species and assigns a buffer to these. There is a primary focus on habitats, nesting and lekking sites and land use restrictions. This is appropriate where data are plentiful but the use of further data such as GPS tracking might be beneficial to refine certain assumptions about key wildlife area delineation.

Input data were rasterized at a ground sample distance of 30 m. A Boolean map of areas suitable for wind development was generated by excluding lands with potential engineering and land use restrictions. Isolated areas too small to support commercial wind development were removed by smoothing the results with a 1 km radius moving window, and patches less than 20 km^2 were removed. To identify suitable wind development areas with low risk of wildlife conflicts, wildlife data layers were subtracted from the initial Boolean suitability map.

The current map area covers the U.S 'Wind Belt' - a 17-state region of the central U.S, which encompasses ~80% of the national planned onshore wind capacity. This map is a significant advancement from the former Site Wind Right tool covering the Central Great Plains and previous exercises in this region, such as the, Nebraska Game and Parks Commission 'Wind and Wildlife' map.

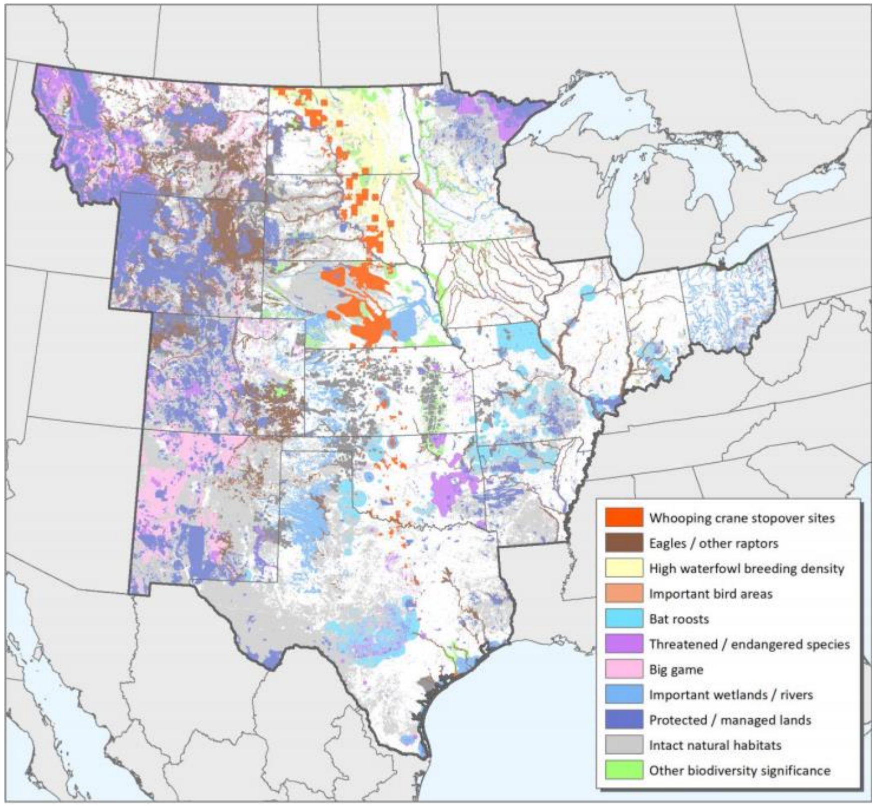
Additional features
This map presents one of the better web viewer tools for identifying potential conflicts with wind energy development siting areas. It permits the user to view the sensitivity layers and clearly identify zones of potential 'low-risk development', which can be measured online.

The map includes 10 forms of potential engineering and land use restrictions including airfields, special use airspace, radar stations, developed areas, existing wind facilities, excessive slope, water and wetlands, poor wind resource, negative relative elevation and statutory setbacks.

Uptake
The tool is well known amongst relevant stakeholders, however, there has so far been limited uptake. The tool has become more

Examples of wildlife sensitivity mapping

Site Wind Right (Low-impact Wind Mapping Tool) (4/5)



Site Wind Right map identifying sensitive natural habitats and distributions of wildlife species that may be adversely affected by wind energy.

Examples of wildlife sensitivity mapping

Site Wind Right (Low-impact Wind Mapping Tool) (5/5)

widely relevant since its update and geographic expansion. The recognition this map has gained is demonstrated by its creators having received the Climate Adaptation Leadership Awards for Natural Resources from the Association of Fish and Wildlife Agencies.

Effectiveness

This map presents a novel approach for identifying sites where wind energy and wildlife are compatible. However, the delineation of sensitive wildlife habitats is not exhaustive and operational mitigation may be required to reduce mortality. It is likely that the map will continue to improve over time as data improves and the wind industry progresses. The mapping tool does not conduct a detailed comparison between conflicting land uses and does not attempt to assign relative sensitivity scores or provide downloadable reports.

Adaptability

The methods for freely displaying information to any relevant stakeholders (e.g. wind energy purchasers, wind project developers, wind energy project financiers, transmission planners, and the public) can be readily converted to other regions. The progression of this map from the Central Great Plains to 17-states across the central U.S, demonstrates the ability to upscale these methods to large regions. Similar, versatile methods and mapping capabilities could be replicated across European Union countries in the same way.

References

Fargione, J., Kiesecker, J., Slaats, M. J. and Olimb, S. (2012) Wind and wildlife in the Northern Great Plains: identifying low-impact areas for wind development. *PLoS One*, 7(7), p.e41468.

Obermeyer, B., Manes, R., Kiesecker, J., Fargione, J. and Sochi, K. (2011) Development by design: mitigating wind development's impacts on wildlife in Kansas. *PLoS One*, 6(10), p.e26698.

Examples of wildlife sensitivity mapping

BFN EE100 - Nature-compatible energy supply from 100% renewable technologies by 2050 (1/3)

Bundesamt Für Naturschutz (BFN)

Summary

The BFN EE 100 project aimed to investigate whether ecologically-sound energy transition in Germany is possible and to what extent energy policy objectives could be combined with nature conservation objectives.

The tool is scenario-based and aims to be able to determine national area potentials and potential yields across Germany until 2050, with the objective of avoiding negative conflicts with nature conservation and local communities. The focus was on wind power and photovoltaic technology, and the scenarios represent snapshots of the state in the year 2050 based on integrating varying technologies (e.g. higher-performance turbines were assumed in Scenario 2). Areas in Germany that are potentially suitable for renewable energy development were identified taking into account the risks to humans and nature, i.e. areas suitable for development where no adverse effects are expected. These included protected sites as well as the areas used by 34 species considered sensitive to renewable energy development. These areas were then removed from the energy prediction models.

This GIS-tool was developed for the Federal Republic of Germany but can also be used at a regional-scale. The results illustrate that renewable energy development up to 2050 can efficiently limit the space required for such developments and any associated conflicts will be minimal. Final decisions relating to the siting of wind turbines are made at lower planning levels, and the tool has not yet been used for this purpose, however this would be technically possible.

Examples of wildlife sensitivity mapping

BFN EE100 - Nature-compatible energy supply from 100% renewable technologies by 2050 (2/3)

Geographic scope	National
Renewable energy sector	Onshore wind, Solar
Taxonomic focus	Birds (34 species of proven sensitivity), Habitats (grasslands, heath and scrub, rivers, forests), protected sites
Intended users	Planning authorities, Government agencies, Consultancies
Access	Restricted
Format	GIS shapefile, but map and GIS tool due to be refined in subsequent project.
Data sources	Species records, habitat maps, conservation sites, topography, infrastructure maps
Factors contributing to the calculation of sensitivity	National conservation status, European conservation status. Also integrated published information on recommended distances of turbines from important areas for birds, and for breeding sites of selected species.
Intended data update cycle	Ongoing follow-up and updates anticipated (including refinements to the GIS-tool and assumptions).
Use in planning process	Developed by Government, not formally integrated within the planning process, and not currently used by others (Regional Authorities, NGOs etc.).
Percentage of siting decisions in which the tool is utilised	None yet

Examples of wildlife sensitivity mapping

BFN EE100 - Nature-compatible energy supply from 100% renewable technologies by 2050 (3/3)

Data
The analyses included nature conservation data taken from the Atlas Deutscher Brutvogelarten (ADEBAR - Atlas of Breeding Birds in Germany) for the 34 species that are proven sensitive to wind energy development (based on LAG VSW 2014), as well as existing and future protected sites (Ramsar, Natura 2000).

Analytical approach
Important nature conservation areas were identified and the areas excluded from the areas proposed for future development and included in the various scenarios. A 200 m buffer was applied to protected sites. The spatial resolution of the distribution data available for vulnerable bird species is relatively crude (i.e. available in grids of several kilometres) and therefore does not show the exact location of the records. Sensitivity was devised through a GIS model.

Additional features
The tool is currently only available as a report, but a GIS tool may be available in due course.

Uptake
NA

Effectiveness
The tool focuses on determining energy yields under various scenarios based on the implementation of various technologies. Although areas sensitive for nature conservation are represented spatially and excluded from the energy yield models, the tool is not a sensitivity mapping approach per se. The aim of the research project was to demonstrate the attainability of national renewable energy targets.

Adaptability
NA

Examples of wildlife sensitivity mapping

Greek national wind farm sensitivity map for birds (1/5)

Hellenic Ornithological Society (HOS)

Summary

The project aimed to identify highly sensitive sites in Greece that could be included in national wind farm exclusion zones. The map used five distinct criteria of equal importance to determine areas of high sensitivity to wind farm development. Unlike many maps, this did not intend to provide a hierarchical classification of sensitive areas in Greece, but rather a map of proposed exclusion zones, which are all deemed critical for conservation of vulnerable bird species. In total, the area of proposed exclusion covers 25% of Greece with more than 400 uninhabited islets included. The terrestrial areas of the exclusion zone cover about 68% of the terrestrial SPA network and 50% of Natura 2000 network.

Data

The map utilises data from relevant scientific papers to identify adequate buffer zone extent, potential issues resulting from habitat changes, barrier and displacement effects, and mortality due to collision. Additional sources, such as species included on Annex 1 of the Birds Directive (79/409/EEC) and the Greek Red Data Book of Rare and Threatened Animals were used.

The map contains information on 21 species, including 15 raptors, three waterbirds and three seabirds, plus wetland congregatory species at Ramsar sites.

Sensitive areas selection criteria:

I. IBAs and SPAs that have been identified as migration-bottlenecks.
II. Ramsar sites with a 3 km buffer zones around their boundaries.
III. IBAs and SPAs with qualifying (trigger) species most threatened by wind farms and major pelican flyways.
IV. Large raptor breeding sites not excluded by criteria I, II or

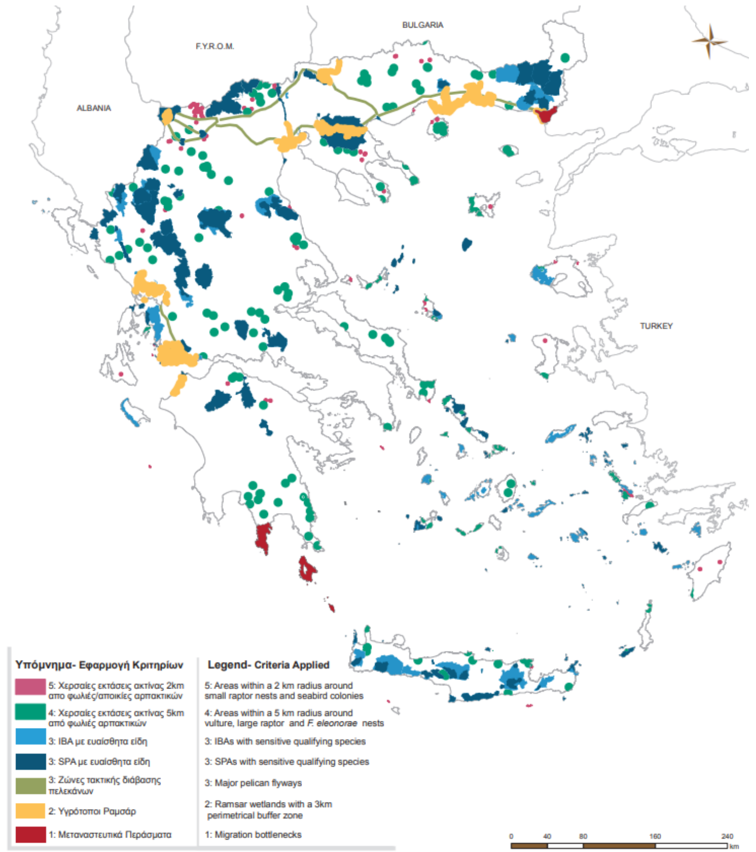
Examples of wildlife sensitivity mapping

Greek national wind farm sensitivity map for birds (2/5)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Seabirds, Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons)
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs , General public
Access	Public
Format	Static map and GIS shapefile
Data sources	Species range maps, Species records, Migration routes, Conservation sites
Factors contributing to the calculation of sensitivity	An in-depth review considered a range of species specific factors including, Proportion of regional population, Global conservation status, Regional conservation status, National conservation status, Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.), Collision vulnerability, Barrier effect vulnerability, Displacement vulnerability
Intended data update cycle	>10 years
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

Greek national wind farm sensitivity map for birds (3/5)



Map from the report showing the proposed exclusion zones from wind farm development after the application of five ornithological sensitivity criteria.

Examples of wildlife sensitivity mapping

Greek national wind farm sensitivity map for birds (4/5)

III, with a 5 km buffer zone.

V. Small raptor and seabird breeding sites not excluded by criteria I, II or III, with a 2 km buffer zone.

The data has not been updated since 2010 when the map was created. Marine IBA and SPA data is not currently included, as their identification and delineation were at the time ongoing, however, there is a desire to integrate them in the future.

Analytical approach
A simple and easily replicable approach was used, involving overlaying spatial boundaries for areas deemed inappropriate for wind development. The method does not calculate a sensitivity index for species and sites, but does produce clear exclusion zones.

Additional features
The HOS report is currently only available in Greek with an English summary and English legend.

Uptake
The map is used for various reasons by administrative authorities, courts, consultants, engineers and scientists.

Effectiveness
This map utilises a simple mechanism for delineating wind farm exclusion zones that is perhaps less sophisticated than other examples of wildlife sensitivity mapping. The map is not comprehensive since it was not possible or practical to include other sensitive species and their critical sites. This information cannot be included, due to the lack of readily digitised and available data at a national scale. There is also a very poor coverage of marine sites, especially IBAs and SPAs, as their identification and mapping is incomplete in Greece. The map has not yet been updated.

This map provides a good example of a nationwide study that can be viewed alongside the WWF's more detailed regional map of Thrace. These both examine the efficacy of exclusion zones and consider the opportunity for renewable energy targets to be met outside these zones.

Examples of wildlife sensitivity mapping

Greek national wind farm sensitivity map for birds (5/5)

Adaptability
The sensitivity map is expected to evolve in the future with the incorporation of more detailed data, for instance, the inclusion of marine IBAs.

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (1/7)

DOPPS – BirdLife Slovenia

Summary

This nationwide map was inspired by the first bird sensitivity map of Scotland launched by the RSPB in 2006 and the authors of that map provided considerable input. The mapping process consisted of a simple overlay of sensitive species and areas, producing a 1x1km raster grid with four colours depicting the particular sensitivity levels. Results from the mapping process show that Slovenia is not a highly sensitive landscape to wind farm placement regarding sensitive species of birds. Areas of high sensitivity cover just 15% of Slovenian territory, with moderately sensitive areas covering a further 15%. The project demonstrated that areas of planned wind expansion have limited overlap with sensitive areas. Furthermore, the results of the sensitivity mapping have helped guide bird-friendly deployment of wind energy across the country.

Data

The considerations of this map included:

1. Distribution of sensitive species
2. Distribution of rare species
3. Congregation areas
4. Locations of reserves

The list of sensitive species was composed following a comprehensive study of available literature that included up-to-date knowledge of the impacts that wind farms in Europe and the rest of the world have on birds. One key consideration that DOPPS took on board was to identify those larger-bodied species that would be most at risk. Furthermore, birds of prey and water birds were identified as groups of birds that would be expected to contain the most sensitive species. Other groups included grouse and owls. Good data were available for most sensitive and rare species except the Short-toed Snake-eagle

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (2/7)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Birds of Prey, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Phasianidae (pheasants), Passerines
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public / Partially restricted
Format	Static map and GIS shapefile
Data sources	Species range maps, Species records, Habitat maps, Migration routes, Conservation sites, Topography
Factors contributing to the calculation of sensitivity	Proportion of national population, National conservation status, EU conservation status (Nature directives), Species morphology (flight style, eyesight etc.), Species behaviour (flight height, degree of wariness etc.), Migratory behaviour (timing, routes etc.), Displacement and collision vulnerabilities
Intended data update cycle	Map update in future subject to funding
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	81-100%

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (3/7)

Circaetus gallicus whose territories are still poorly known.

Additionally, migratory corridors are poorly known. Recent surveys improved the knowledge considerably and it would be good to update the sensitivity map in the future with the inclusion of further research on migration routes.

Analytical Approach
The following rasterization method was used and subsequently 'blurred' to protect sensitive species whilst still providing an accurate overview:

- The national territory was divided with a 1 x 1 km square grid;
- Each square was assigned one of the four colours with regard to the share of the surface area, which is covered by highly sensitive (XO – red) and moderately sensitive (zo – yellow) area:
  - XOA – dark red – the square is mostly covered by a highly sensitive area
  - XOB – pink – the square is partially covered by a highly sensitive area, possibly only marginally
  - zoA – dark yellow – the square is not even marginally covered by a highly sensitive area, but to a great extent by a moderately sensitive area.
  - zoB – light yellow – the square is not even marginally covered by a highly sensitive area; however, it is partially covered by a moderately sensitive area, possibly only marginally
  - No colour – the square is not even marginally covered by a highly or moderately sensitive area

A rigorously selected set of 17 sensitive species were assessed against criteria for sensitivity (sensitive and rare species plus congregation areas and reserves). Data are generally good (except for the migration corridors) and sensitivity criteria are considered to be reasonable.

The zo (medium sensitivity) was assigned to cover the potential distribution of Short-toed Snake-eagle within SPAs. As territories are poorly known, the map shows lower XO (high sensitivity) coverage then would be realistic. This is especially problematic as strong wind resource encourages developers to prospect for

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (4/7)

potential locations in the Mediterranean part of the country, where these eagles occur.

Some changes of the criteria have been proposed, e.g. for Western Capercaillie *Tetrao urogallus* there is XO (high sensitivity) only for those leks within IBAs. This should ideally be changed, as the species is declining in Slovenia. DOPPS believe all Western Capercaillie leks should be classified as XO (highly sensitive). Because of the Capercaillie declines, many leks have been abandoned (probably permanently), these should therefore be removed from the sensitivity map. On the other hand, those remaining leks are now more valuable and sensitive, so the criteria associated with these should now be more sensitive.

Additional Features

In Slovenia, only the sensitive areas publication map is freely accessible to the public. The publication map was made on the basis of a detailed combined sensitivity map, in which the details are blurred with the rasterization.

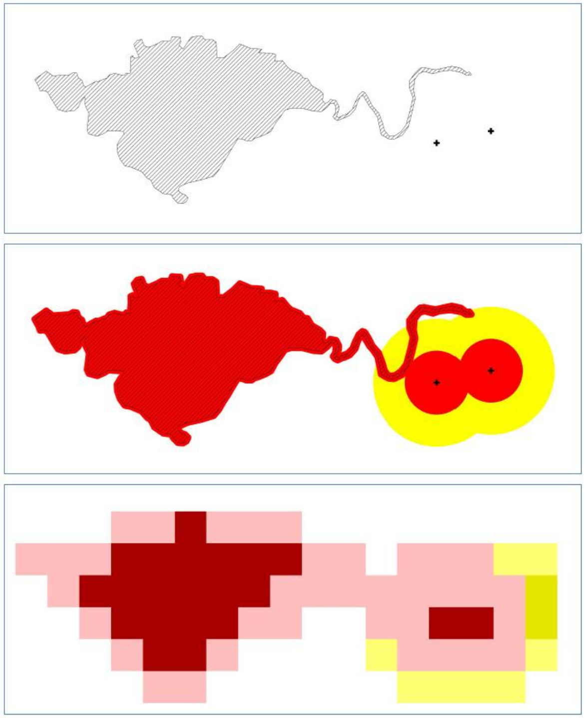
Uptake

The uptake of this map has been greater than with many other sensitivity mapping projects considering its use is not formally required. This is in part because the map clearly demonstrates that much of the available wind resource is in areas not deemed sensitive for birds. The Government of Slovenia published a draft proposal for a new National Energy Program, with potential wind farms based on a study identifying suitable areas for wind energy exploitation based on a minimum threshold of 4.5m/s at 50m (Mlakar *et al*. 2011). When the map was overlaid with the possible wind farm areas proposed in the draft, it showed that highly sensitive areas cover only 7% of potential wind farm areas, while moderately sensitive areas cover a further 26%. This means that more than 18,600 hectares of the land suitable for wind farms does not fall within sensitive areas.

The National Nature Conservation Institute have adopted the map and most developers now approach DOPPS to discuss potential locations in advance of development. The simplicity of the map and the reputation of DOPPS may be further reasons for the high level of uptake.

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (5/7)



Effectiveness

The map has effectively guided the wind farm development initiatives away from the most sensitive areas for birds. It would, however, be good to update the sensitivity map in future to ensure its continual efficacy.

Tracking data would be particularly useful to add more certainty to sensitivity ratings and migration corridors. Many of the sensitivity ratings are based on assumptions and may underestimate sensitivity.

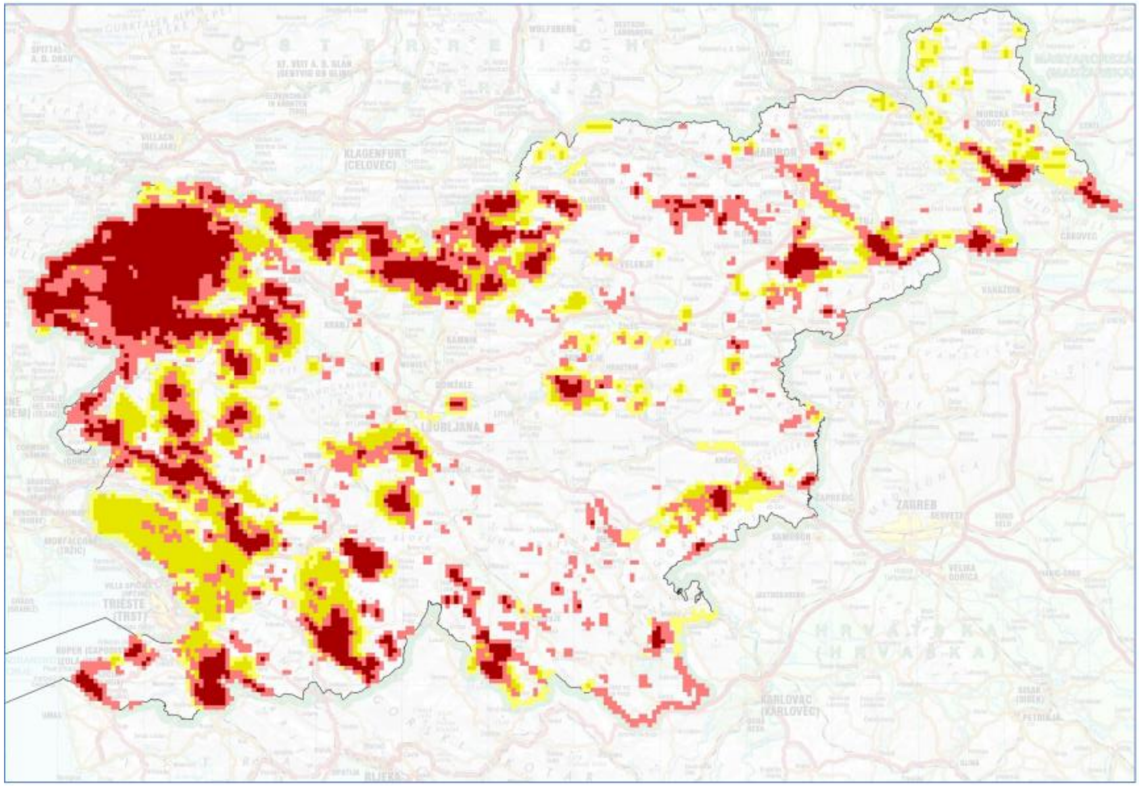
Adaptability

The map could be easily adapted as additional species or criteria can be readily added with a simple re-rasterization process. Because individual species maps are created before compiling
the overall sensitivity map, many additional datasets and species of concern could be added. There is great potential for a subsequent version of the map to significantly update the data and interface whilst still maintaining the sensitive locations of certain species. The method implemented in Slovenia is particularly simple and the basics could be readily replicated at a larger scale.

An example of how the data was rasterised for the Slovenian Sensitivity Map (in this case a nature reserve and two Black Kite nests).

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (6/7)



Publication sensitivity map from the report. Dark red – 1x1 km squares that are almost entirely covered by high sensitive areas; pink – squares that are at least partly covered by high sensitive areas; dark yellow – squares that are not even marginally covered by high sensitive areas, but are almost entirely covered by medium sensitive areas; light yellow – squares covered only partly by medium sensitive areas.

Examples of wildlife sensitivity mapping

Slovenian national wind farm sensitivity map for birds (7/7)

Reference

Mlakar, A., Cigoj, N., Pavlovič, L.Š., Trnovšek, L., Žerdin, M., Podgornik, A., Staničić, D. and Urbančič, A. (2011) Celovit pregled potencialno ustreznih območij za izkoriščanje vetrne energije: strokovna podlaga za Nacionalni energetski program (obdobje 2010-2030). Aquarius doo Ljubljana.

Examples of wildlife sensitivity mapping

A spatial conservation prioritisation approach for protecting marine birds given proposed offshore wind energy development (USA) (1/3)

University of Massachusetts Amherst

Summary
Numerous offshore wind energy developments (OWEDs) have been proposed along the Atlantic Coast in North America, and development pressure was a catalyst for marine spatial planning to identify suitable areas for OWED. This project was funded by grants from the US Department of Energy, the American Recovery and Reinvestment Act, and the State of Rhode Island.

Distributions of marine birds off the coast of southern New England were modelled using two species distribution modelling approaches: density surface modelling and presence–absence modelling. The models were used to predict the distribution of marine birds across the Rhode Island Ocean Special Area Management Plan.

Data
Data from 41 aerial transect surveys carried out between October 2010 and July 2012 were used. These surveys were carried out in the Rhode Island Ocean Special Area Management Plan study area, which encompasses approximately 3,800 km^2.

Analytical approach
Spatial distribution models were developed for marine birds from aerial surveys conducted from 2010 to 2012 off the coast of Rhode Island. For seven groups of marine birds, either a density surface model or a presence–absence model was produced that incorporated relevant environmental covariates.

For each species or species group, distribution models were developed for the season in which they were most abundant. Alcids, Common Eiders *Somateria mollissima*, Northern Gannets *Morus bassanus*, scoters and Common Loons *Gavia immer* were more abundant in winter, and storm petrels and terns were most

Examples of wildlife sensitivity mapping

A spatial conservation prioritisation approach for protecting marine birds given proposed offshore wind energy development (2/3)

Geographic scope	Regional
Renewable energy sector	Offshore wind
Taxonomic focus	Seabirds, Anseriformes (ducks, geese, swans)
Intended users	NA
Access	Fully restricted
Format	Static map in report
Data sources	Species records
Factors contributing to the calculation of sensitivity	All marine birds were included
Intended data update cycle	NA
Use in planning process	Developed by Government, not formally integrated within the planning process, paper regularly cited (best practice).
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

A spatial conservation prioritisation approach for protecting marine birds given proposed offshore wind energy development (3/3)

abundant in summer. For each species or group, they attempted to fit a density surface model (DSM). For Common Eiders and scoters, this was not possible due to the small sample of records, and instead binary presence or absence was modelled. The DSM was constructed in two steps. Firstly, distance sampling was used to generate abundances along the line transects, and a generalised additive model was then applied with explanatory variables (six abiotic explanatory variables) provided by spatially referenced environmental covariates.

Sites with high marine bird conservation priority were delineated using spatial conservation prioritisation software (Zonation v. 3.1). Shallow nearshore waters had the highest conservation priority overall, while some key offshore areas of high priority were identified also. Hypothetical OWEDs placed in conservation priority areas significantly reduced the overall distribution of focal species. Currently proposed OWED sites are located in areas of relatively low conservation priority and so would not substantially reduce the overall distribution of marine birds. This modelling framework should be helpful to decision makers as they evaluate proposed siting locations of OWEDs.

Additional features
NA

Uptake
The map is only available within a published peer-reviewed paper.

Effectiveness
The extent of interest in this work is unknown, however, the methods applied to determine the seabird distribution (density surface models based on distance sampling and generalised additive modelling with explanatory variables) have been used successfully elsewhere, in similar studies (e.g. Bradbury *et al.* 2013).

Adaptability
NA

Examples of wildlife sensitivity mapping

American Bird Conservancy Wind Risk Assessment Map (1/4)

URL

American Bird Conservancy

Summary

The American Bird Conservancy's (ABC) Wind Development Bird Risk Map aims to promote bird-smart wind energy siting (for onshore wind) by highlighting the locations of important bird areas that should be avoided by wind developers or approached with care. Although not a substitute for detailed impact assessment, wind developers and state and federal regulatory agencies are encouraged to use this map as a tool to aid in siting decisions.

Data

The bird data were derived from a variety of sources. Primary sources include ABC's list of the 500 most Important Bird Areas in the U.S., data on key sage-grouse areas from the Bureau of Land Management, and data on the migration corridor of the Whooping Crane from the U.S. Fish and Wildlife Service (FWS). "Critical Habitat" designated by FWS as authorised by the Endangered Species Act was downloaded from the FWS website. Site boundaries are either provided by existing federal or other GIS layers, or produced by ABC using the best available data, maps, and expert staff opinion. There is currently insufficient quantitative data available to set numeric boundaries for the "edges" of most migration corridors, and these may also change from year to year depending on weather and other conditions. The boundaries of these areas are therefore set based on ABC's best expert judgment as to where the greatest concentration of birds will be present during regular migration periods.

Another very useful source of information on migration patterns were the animated migration maps produced by the Cornell Laboratory of Ornithology. California, Illinois, Montana, and North Carolina State Audubon Chapters also made their state IBAs available in polygon form. Boundaries for Key Habitat Areas are based on greatest breeding densities from Breeding Bird

Examples of wildlife sensitivity mapping

American Bird Conservancy Wind Risk Assessment Map (2/4)

Geographic scope	National
Renewable energy sector	Onshore wind and limited offshore wind
Taxonomic focus	Birds of Prey, Seabirds, Waders, Anseriformes (ducks, geese, swans), Ciconiiformes (storks), Pelecaniformes (pelicans, ibises, spoonbills, herons), Phasianidae (pheasants), Otididae (bustards), Apodidae (swifts), Passerines
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs, General public
Access	Public
Format	Static map and Google Earth layer
Data sources	Species range maps, Species records, Habitat maps, Migration routes, Conservation sites, Infrastructure maps
Factors contributing to the calculation of sensitivity	Global conservation status (e.g. IUCN Red List), Regional conservation status, National conservation status, Habitat sensitivity
Intended data update cycle	Not planned
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs).
Percentage of siting decisions in which the tool is utilised	Unknown

Examples of wildlife sensitivity mapping

American Bird Conservancy Wind Risk Assessment Map (3/4)

Survey (BBS) maps combined with expert opinion. For the few Red WatchList species where BBS data were unavailable, entire species range boundaries were used.

Analytical approach

Site boundaries were compiled across layers and are illustrated as either Critically Important Areas (Red boundaries) or Areas of High Importance (orange).

- The Critically Important Areas are defined as the crucial migration routes, breeding habitats, wildlife refuges and parks, which it is advised to avoid at all costs. They include IBAs with congregations in excess of 500,000 migratory birds at any point during the year, or those that support rare WatchList species, or species that have specific and limited habitat requirements. These crucial areas also include bottleneck areas for migrating birds, critical habitat designated for birds listed under the Endangered Species Act, as well as important habitat for these species not yet designated.
- Areas of High Importance delineated in solid orange include the globally important bird areas. Other sites delineated with a tint of orange include key migration corridors, key habitat areas for species on the Red WatchList plus both widespread eagle species and Ferruginous Hawk *Buteo regalis*. This category also includes marine IBAs where bird usage is also seasonal.

Additional features

Downloadable Google Earth layers are available on a state-by-state basis upon request.

Additional methodology and data sources

Uptake

The map has not been updated since August 2014, but it has been used as a reference for public scoping of newly proposed wind energy development projects.

Effectiveness

The online platform ensures that this tool is readily available and can be interrogated at finer spatial scales.

Examples of wildlife sensitivity mapping

American Bird Conservancy Wind Risk Assessment Map (4/4)

Although a useful tool for the early stages of planning ABC's wind development risk map comprises a relatively simple compilation of the boundaries of important bird sites.

Adaptability

The approach used to develop this tool could be extended spatially, as well as to include other taxa. However, it would be recommended with increasing layers to integrate some measure of collision risk to enable refinement of the final map.

Examples of wildlife sensitivity mapping

Mapping risk for a bat species in the Molise region, Italy (1/3)

University of Molise, University of Porto, University of Naples Federico II and the University of Bristol

Summary

This study examined the impact of wind turbines on habitat connectivity in relation to bats based on a species distribution model. The model was tested on *Nyctalus leisleri* in an area of Central Italy. The species was selected because of its migratory behaviour and known vulnerability to wind farms. The project aimed to identify the most suitable areas for the species and the major corridors between these areas. Thereafter it was possible to identify the turbines posing the greatest impacts on major connectivity routes. This information was then used to identify suitable mitigation measures.

Data

The model was based on data gathered in 2010 and 2011 based on a survey of 165 locations at wind farm and control areas across different areas of the region, and habitat information using the Corine Landcover dataset, reclassifying the data into 16 categories that are ecologically meaningful for this species.

Analytical approach

The Species Distribution Model was developed using the maximum entropy algorithm MaxEnt which has good proven performance with small datasets and presence data only, which was especially important as the nocturnal and elusive behaviour of bats makes them prone to the existence of false absences.

The connectivity analysis was performed using a landscape resistance surface map that synthesised the critical factors that might influence the commuting movements of *N. leisleri*. Existing and planned wind turbines were overlapped onto the species commuting corridors to identify areas to be preserved (no new wind turbines), curtailment areas (where a cut in the wind turbine speed should be considered), and areas where the expansion of wind farms did not interfere with this species.

Examples of wildlife sensitivity mapping

Mapping risk for a bat species in the Molise region, Italy (2/3)

Geographic scope	Regional
Renewable energy sector	Onshore wind
Taxonomic focus	Leisler's Bat *Nyctalus leisleri*
Intended users	Planning authorities, Government agencies, Consultancies
Access	Fully restricted
Format	Static map
Data sources	Species records, Habitat maps, Topography
Factors contributing to the calculation of sensitivity	Species distribution
Intended data update cycle	2-5 years
Use in planning process	Map developed with a government agency. Map formally integrated within the planning process with its use mandatory
Percentage of siting decisions in which the tool is utilised	1-20%

Examples of wildlife sensitivity mapping

Mapping risk for a bat species in the Molise region, Italy (3/3)

Additional features
NA

Uptake
The results are used in the planning process. Subsequently, there have been attempts to promote the use of this planning tool in other regions, but there has been no uptake so far.

Effectiveness
The tool is only available in the published paper, which does limit uptake and usage, and interrogation at finer spatial scales. The approach used is clear and well set out and could be extended to other areas. This is one of few examples attempting to identify sensitive areas for taxa other than birds in relation to renewable development. There are reservations with respect to developing sensitivity maps for bats because of the potential for false absences, but to some extent this study has attempted to address this by the analyses chosen, using MaxEnt etc. Further ground-truthing of the results achieved may help to generate confidence in further development of sensitivity mapping with respect to bats.

Adaptability
NA

References
Roscioni, F., Rebelo, H., Russo, D.Carranza, M. L., Di Febrarro, M. and Loy, A. (2014) A modelling approach to infer the effects of wind farms on landscape connectivity for bats. *Landscape Ecology* 29: 891-903.

Examples of wildlife sensitivity mapping

Assessment of wind farm impacts on large carnivores in Croatia (1/6)

University of Zagreb Veterinary Faculty and Croatian Agency for Environment and Nature

Summary

Disturbance and habitat fragmentation are among the largest threats to carnivores in Croatia. Consequently, poorly-planned wind energy development could pose a significant threat to their survival in the region. This sensitivity map was created in 2016 before any national-scale assessments of wind energy deployment opportunities had taken place. It uses data on large carnivore occurrence and related habitat characteristics. The sensitivity map defines nine classes of habitat sensitivity, which are grouped into four categories of suitability for large mammal presence. Individual sensitivity maps were developed for bears, wolves and lynx and a further two maps were produced for bear and wolf reproduction sites. Finally, one combined sensitivity map was created for all three species together.

Data

Animal data:

Observation data came from studies of large carnivores in Croatia and through national monitoring programmes. Research data was collected from 1981 to 2013. This included 34,253 telemetry locations of bears, wolves and lynx and 3,026 other observations. Other observations (dating from 1978 until 2013) included locations of mammal mortalities, animal markings (excrements, urinations, scratch marking, hairs, and vocalization) and other signs like footprints, killed prey, identified den sites and visual observations of large carnivores.

Habitat data:

14 basic and derived spatial datasets (GIS layers) were incorporated into the mapping of habitat suitability. Not all were used for every species since not all were relevant for each species. Available layers included the percentage of agricultural

Examples of wildlife sensitivity mapping

Assessment of wind farm impacts on large carnivores in Croatia (2/6)

Geographic scope	National
Renewable energy sector	Onshore wind
Taxonomic focus	Mammals: Bear, Wolf and Lynx
Intended users	Planning authorities, Government agencies, Consultancies, Conservation NGOs
Access	Public
Format	Static map, GIS Shapefile
Data sources	Species occurrence records, Habitat maps
Factors contributing to the calculation of sensitivity	Distribution, known impacts of wind turbines and additional spatial attributes, Species habitat use, including natural and anthropogenic variables. Species global conservation status, species national conservation status, population connectivity
Intended data update cycle	Planned in future
Use in planning process	Not formally integrated within the planning process, but regularly used (e.g. recommended by authorities, NGOs)
Percentage of siting decisions in which the tool is utilised	41-60%

Examples of wildlife sensitivity mapping

Assessment of wind farm impacts on large carnivores in Croatia (3/6)

land, pastures and forest, densities of roads and humans, distance to forest edge, road, settlement and feeding site, elevation, slope, index of terrain ruggedness and the Shannon Diversity Index.

Analytical approach

Data modelling was performed using Mahalanobis distance multivariate analysis. This method determines how similar certain spatial conditions are to ideal conditions based on the known locations of large carnivores.

The Mahalanobis distance analysis was used to create a grid in which each unit (250 x 250 m square) contained information about the probability that the animal would appear at that location. One map was made for each species, and additional maps for wolf and bear dens. A map was also made showing the probability of the presence of all the carnivores. This combined map was obtained by combining the probability grids of all three large carnivores by taking the maximum value at that location for each grid unit. This means that for example, if in one place, the probability of the presence of a bear was 20%, a lynx 10%, and a wolf 80%, then the final value would be 80%. All grids were reclassified into nine categories with the following ranges of probability of occurrence of the species: up to 5%, 5-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-65%, 65- 80% and 80-100%. These were then grouped into four categories of habitat suitability: High Suitability, Moderate Suitability, Low Suitability and Unsuitable (see Table).

PROBABILITY OF LARGE CARNIVORE OCCURENCE (%) ZVIJERI	CLASSES OF HABITAT SENSITIVITY AND COLOR LEGEND	ALLOWED HABITAT LOSS (%)	CATEGORY (SIGNIFICANCE)
0-5	1	100	UNSUITABLE
5-10	2	90	LOW SUITABILITY
10-20	3	50	
20-30	4	20	MODERATE SUITABILITY
30-40	5	10	
40-50	6	5	
50-65	7	3	HIGH SUITABILITY
65-80	8	2	
80-100	9	1	

Table showing the nine categories based on the likelihood of carnivore occurrence and therefore sensitivity, as well as the four suitability groupings. Habitat with higher suitability for large carnivores is classed as more sensitive.

Examples of wildlife sensitivity mapping

Assessment of wind farm impacts on large carnivores in Croatia (4/6)

The grid was reclassified and further vectorised, with neighbouring identical grid units combined into single polygons, which were then used as spatial units in assessing the overall impact of the wind farm on large carnivores. The area was calculated for each polygon, and the total representation (%) of each habitat class for each of the three large carnivores in the entire study area was determined.

Taking into account that currently, the limited data on the interaction of wolves and wind turbines (Álvaras 2013; Álvaras *et al*. 2011), it was decided that two levels of possible impact would be considered; impact on the general habitat use and impact on location of dens. In the absence of knowledge about the potential gradient of decreasing influence of wind turbines with distance, a radius of 1 km was chosen as the limit of general disturbance, while a radius of 2 km was chosen as the limit of disturbance for dens. For bears and lynx, the same values for the disturbance distance were chosen, i.e. radius of 1 km for general disturbance impact, and 2 km for dens as these are particularly sensitive places, important for reproductive success.

Additional Features

However, a year after the original map was released, a follow-up analysis was conducted focussing on wolves; Passoni *et al*. 2017. This study identified an optimal subset of planned wind farms that would meet energy targets whilst minimising potential impacts on wolves.

Marxan analysis was used to find the optimal trade-off between energy capacity and overlap with critical wolf reproduction habitat. This project showed that it was possible to meet national energy targets with only 31% of proposed wind farms, deployed in a way that would reduce the potential ecological cost by 91%. The data from this follow-up analysis are expected to be included in future updates of the original tool.

Uptake

The project was made public in 2016, but not peer-reviewed. However, both the original sensitivity map and subsequent research on wolves are used to inform Environmental Impact Assessments. The fact that the study was jointly carried out by The University of Zagreb and the Croatian Ministry for

Examples of wildlife sensitivity mapping

Assessment of wind farm impacts on large carnivores in Croatia (5/6)

Environment and Nature suggests that the results should have higher recognition in the planning process.

Effectiveness
The sensitivity mapping is accompanied with guidelines and information on the habitat use of carnivores. Therefore, the document can be used to evaluate and inform all environmental and nature related assessment procedures including SEAs, EIAs, and AAs. The analysis and guidelines include advice about which areas to prioritise for avoidance. It also includes an estimation of the permissible losses of each habitat class, if it is unavoidable to enter the high suitability zones. These values were based on the results of the sensitivity mapping, which quantified the extent of available habitat for carnivores.

The maps were effective in mapping the suitability of habitat for three carnivore species. Its effectiveness could be improved by additional considerations of renewable energy targets and the likelihood of safe future developments with appropriate grid connectivity.

Adaptability
This study is a unique exercise in Europe due to the high quality of carnivore occurrence data in Croatia. Similar approaches could be replicated for any of the three species across their ranges as long as habitat data and occurrence data exist. Passoni *et al.* (2017) were able to incorporate energy targets and determine the suitability of a subset of planned installations. This makes the output of this type of analysis more relevant and applicable to the industry so would be desirable to include in any similar studies. Future updates will also include modelling of movement corridors for large carnivores, as these data are now available.

References

Álvaras, F. (2013) Wolves and wind power turbines in Portugal.

Álvaras, F., Rio-Maior, H., Roque, S., Nakamura, M., Cadete, D., Pinto, S. and Petrucci-Fonseca, F. (2011) *Assessing ecological responses of wolves to wind power plants in Portugal: methodological constrains and conservation implications*. In

Examples of wildlife sensitivity mapping

Assessment of wind farm impacts on large carnivores in Croatia (6/6)

Conference on Wind energy and Wildlife Impacts 2-5 May 2011, May, R., Bevanger, K., eds. (Trondheim, Norway, NINA), p 140.

Passoni, G., Rowcliffe, J.M., Whiteman, A., Huber, D. and Kusak, J. (2017) Framework for strategic wind farm site prioritisation based on modelled wolf reproduction habitat in Croatia. *European Journal of Wildlife Research*, 63(2), p.38

Spatial data

- Overview of spatial data

SPATIAL BIODIVERSITY DATA

- Atlas grid
- Observation records
- Species ranges
- Tracking data
- Conservation areas
- Habitat and vegetation

OTHER TYPES OF SPATIAL DATA

- Topography
- Resource
- Existing installations and transmission

Spatial data

Overview of spatial data (1/3)

Wildlife sensitivity maps should utilise the most accurate and up-to-date data on the distribution and abundance of potentially sensitive species and habitats. Ideally, such data will be collected systematically using a standardised protocol such as that used for the European Breeding Bird Atlas developed by the European Bird Census Council. However, often data is generated in an ad hoc manner, such as with observation records collated through citizen science projects or through field surveys limited in geographic scope. Biases in survey effort or focus should be acknowledged and the level of certainty clearly specified. Often species distributions will need to be inferred from generalised species range maps, habitat maps or tracking data. Again, any underlying assumptions and shortcomings associated with such models should be clearly specified.

It should be recognised that the current distribution of a species may be much more restricted that it was historically and indeed more restricted than that aimed for in conservation recovery targets. Therefore, it may be preferable to develop predicted range maps based on a desired distribution following population recovery and restoration.

Inevitably, the quality of data, and the level of knowledge on now best to interpret it, will vary considerably between different regions and taxonomic groups. For example, far less data exists on the distribution of bat species within Europe than bird species. Even where data is limited and the resultant sensitivity maps are crude and preliminary, they still serve as a useful early stage planning tool. It is important, however, to clearly acknowledged the limitations.

There are numerous datasets on the distribution and abundance of European wildlife. There are also several abiotic and biotic environmental spatial datasets that can be useful as explanatory variables to model distributions.

This section outlines the types of spatial biodiversity data, such as species observation records and conservation area

Spatial data

Overview of spatial data (2/3)

boundaries, which can be utilised in the development of wildlife sensitivity maps. It also discusses other types of spatial data useful in planning renewable energy, such as data on resource potential or existing energy infrastructure. For each type of data, examples are given of useful data sources. These include official datasets compiled by EU Member States and maintained by the European Union, as well as datasets managed by NGOs and academic institutions. All of the datasets listed maintain data relevant to the development of wildlife sensitivity maps, however, ultimately access to the data is at the discretion of the data curators and is not guaranteed.

Important datasets that inform the status and/ or distribution of biodiversity in the European Union include:

URL A broad range of datasets are available through the European Environmental Agency (EEA) website. Through this portal data and information is available through reports submitted on the Birds and Habitats Directives. EU Member States are obliged to report every six years on the status of birds and habitats through Articles 12 and 17 reports respectively. Publicly available data from these reports include tabular data on status and distribution, as well as spatial distribution data available at a standard 10-km grid scale. They include the following datasets:

- URL Article 12 (Birds Directive): Status and distribution from Article 12 reports.
- URL Article 17 (Habitats Directive): Status and distribution from Article 17 reports.

Spatial data

Overview of spatial data (3/3)

URL

Natura 2000: Distribution of Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) designated as part of the EU Birds and Habitats directives, respectively.

Spatial data

Atlas grids (1/2)

Description Wildlife atlases present systematically collated data on species presence or abundance. Typically, a region is gridded and each grid cell is surveyed using a standardised protocol that ensures consistent sampling effort. In some countries, the grid cells follow the latitudes and longitudes - cell intervals of 1 degree, 30 and 15 minutes are often chosen for convenience. In higher latitudes where such an approach leads to grid cells with large differences in area, sizes are more often fixed using grid distances of 1, 2, 5, 10 or 50 km grid intervals. When repeated over different time intervals using comparable methodologies, atlases are a very useful way of documenting changes in presence and abundance.

Type Vector/raster

Pros Chart patterns of bird occurrence over large geographic areas. Often consistent sampling effort.

Cons Gridded data does not often match natural boundaries exactly. Recording effort is often uneven between grid cells. Sometimes it is possible to make corrections for these differences in sampling effort.

Examples

URL The European Breeding Bird Atlas 2 (EBBA2) map contains > 5000 50x50 km squares including information on 500+ breeding species

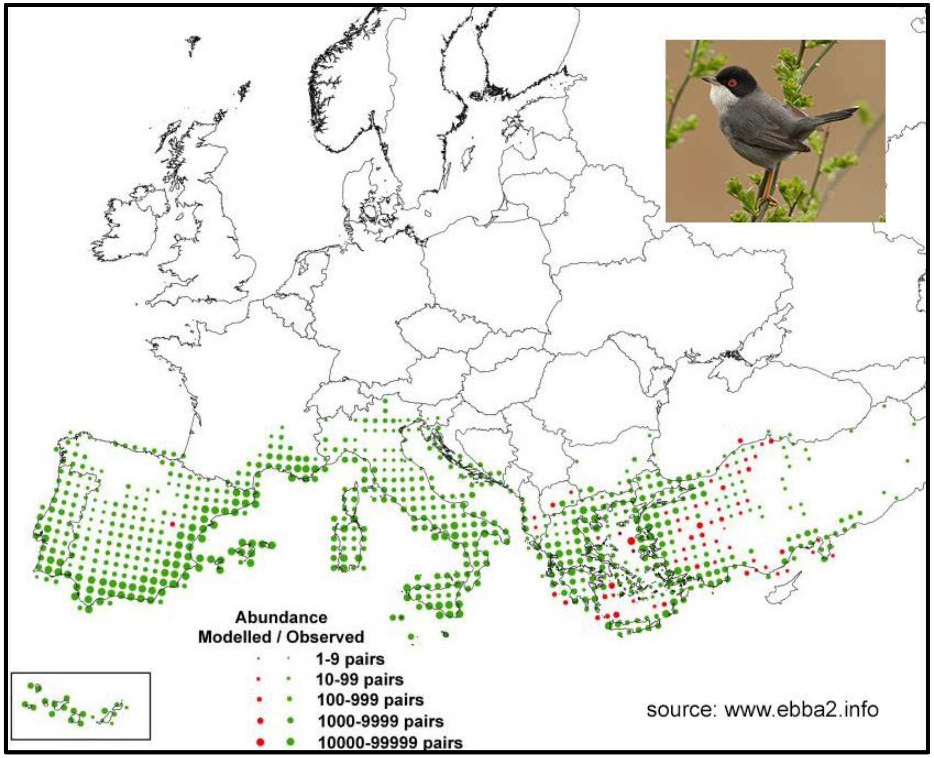
URL The Bird Atlas of Britain and Ireland (2007–11) maps birds in both winter and the breeding season from every inch. It is a partnership between the BTO, BirdWatch Ireland and the Scottish Ornithologists' Club.

Spatial data

Atlas grids (2/2)

The European Marine Observation and Data Network (EMODnet) Atlas of Marine Life provides a combination of tools, models and spatial maps that allow users to visualise marine biological data. The Atlas gives an overview of the marine birds, mammals, reptiles, fish, benthos, algae and plankton that occur in European marine waters.

The European Atlas of Forest Tree Species published by the European Commission is useful resource on the distribution of trees and forested habitats.



European Breeding Bird Atlas documenting breeding evidence for all bird species at 50x50km across Europe. (European Bird Census Council). This is an extract from EBBA2 displaying data for the Sardinian Warbler - due for publication in 2020.

Spatial data

Observation records (1/3)

Description Georeferenced species observation records collated through structured surveys or, increasingly, crowdsourced through amateur naturalists. Georeferenced observation records can be mapped as points to show distribution and abundance.

Type Point

Pros Point densities can be interpolated to generate grid or contour maps.

Cons Potentially unequal distribution of recording effort and therefore high degree of omission error. Techniques exist for adjusting for any differences in sampling effort.

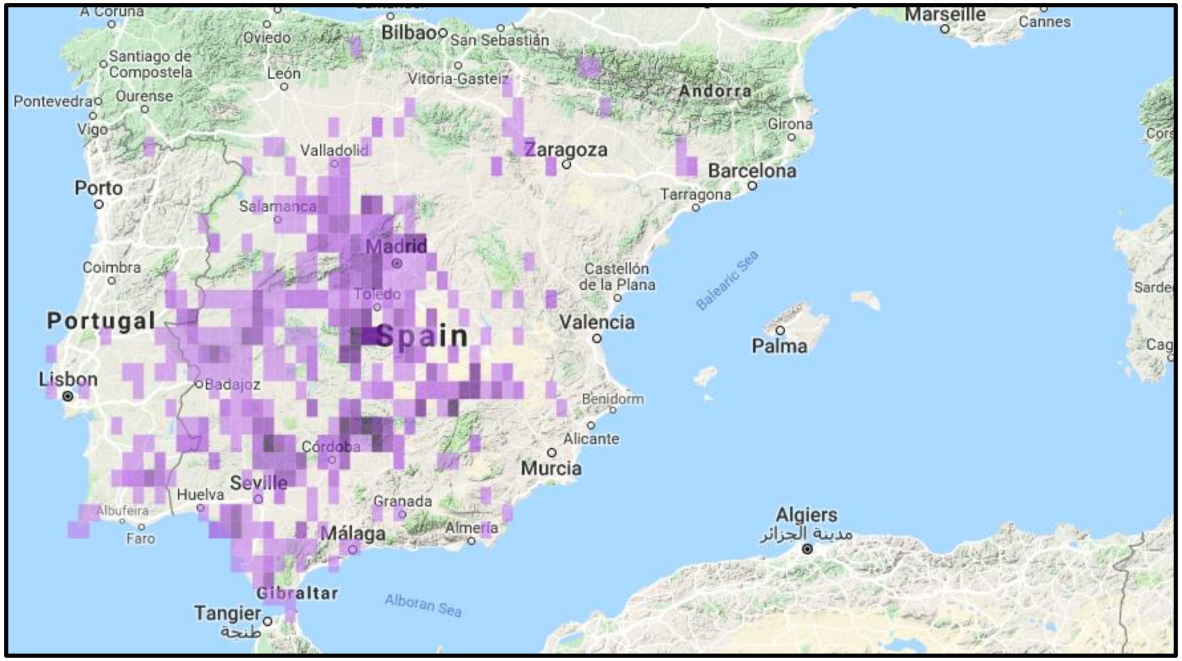
Examples

European Seabirds at Sea (ESAS) database contains at-sea data collected from ships and aircraft using methods described in Tasker *et al*. 1984 and Camphuysen 2004. A strip transect method with distance bands is used for birds on the sea, and snapshot information for flying birds. Data are collected by seabird researchers across north-west Europe and the UK's Joint Nature Conservation Committee (JNCC) and is managed on behalf of partners by the JNCC. Approximately three million counts of seabirds have been collected since 1979. Data are available upon request.

The open-access eBird Basic Dataset (EBD) includes all raw eBird observations and associated metadata. It is updated monthly and available for download. There are also associated packages for processing this particular data in R. Additionally, eBird Observational Datasets are made available through the Global Biodiversity Information Facility.

Spatial data

Observation records (2/3)



eBird observations map for Spanish Imperial Eagle *Aquila adalberti* showing higher reporting rate with darker purple rectangles.

Spatial data

Observation records (3/3)

The Euro Bird Portal is a project by the European Bird Census Council (EBBC) combining 29 institutions across 21 European countries. This repository aggregates data from multiple sources for large-scale spatial analyses. Currently, data are visible through an interactive web viewer. However, as the EBBC project progresses, third parties will be able to access the data and products directly.

BirdTrack is a free online portal for submitting bird records for Britain and Ireland (the availability of this data for the purposes of sensitvity mapping has not been confirmed).

Ornitho portal provides avian data for Austria, France, Germany, Italy, Luxemburg, Poland, Spain (Catalonia and Basque Country) and Switzerland (the availability of this data for the purposes of sensitvity mapping has not been confirmed).

Observation.org is a tool for field observers around the world to record and share their plant and animal sightings (the availability of this data for the purposes of sensitvity mapping has not been confirmed).

The European Biodiversity Portal offers access to biodiversity observations and ecological data, along with tools for sharing or discovering data.

The European Marine Observation and Data Network (EMODnet) biology data portal provides free access to data on temporal and spatial distribution of marine species and species traits from all European regional seas. EMODnet Biology is built upon the World Register of Marine Species and the European Ocean Biogeographic Information System.

Spatial data

Species range maps (1/2)

Description Species range maps depict a species' broad distribution. They typically reflect Extent of Occurrence (EOO), the smallest single area containing all known sites of occurrence. Use of such maps can result in overestimating occurrence. Species Distribution Models can be used to refine range maps so that they better reflect a species' actual presence (Area of occupancy [AOO], the area within the EOO that is occupied by a species). Species Distribution Models (SDMs) combine species data with known environmental parameters to create more accurate forecasts of occurrence. SDMs can also be used to model future distributions based on different scenarios, such as projected climate change or planned species recovery.

Type Polygon

Pros A useful source of data in the absence of observation records or atlas data.

Cons Typically, such maps reflect Extent of Occurrence (EOO), which can result in significant overestimation of occurrence.

Examples

URL The European Environment Agency holds GIS data on the distribution of European species and habitat types. These are aggregated by conservation status per Member State and at the EU-28 level.

URL BirdLife International compiles and maintains digitized distribution maps for all of the world's bird species. These maps are available for through the Integrated Biodiversity Assessment Tool (IBAT).

Spatial data

Species range maps (2/2)

BirdLife International range map for Spanish Imperial Eagle *Aquila adalberti*.

Spatial data

Tracking data (1/2)

Description Data showing successive locations of an animal at specific times and places. Typically from tagged individuals (e.g. GPS tags). Tracking data provide important insights into a species' spatial ecology and can be used to identify key foraging sites or migratory routes. Scientists collect animal movement data by attaching electronic tracking devices to individual animals. These range from Very High Frequency (VHF) Radio Transmitters, which transmit a signal to a researcher's receiver, to GPS and Argos Doppler tags, which convey more precise time and location data and do not rely on a person to make a physical observation.

Type Line

Pros Useful for identifying migration routes, key foraging sites etc.

Cons Typically highly variable recorder effort, with strong bias to certain species in certain locations.

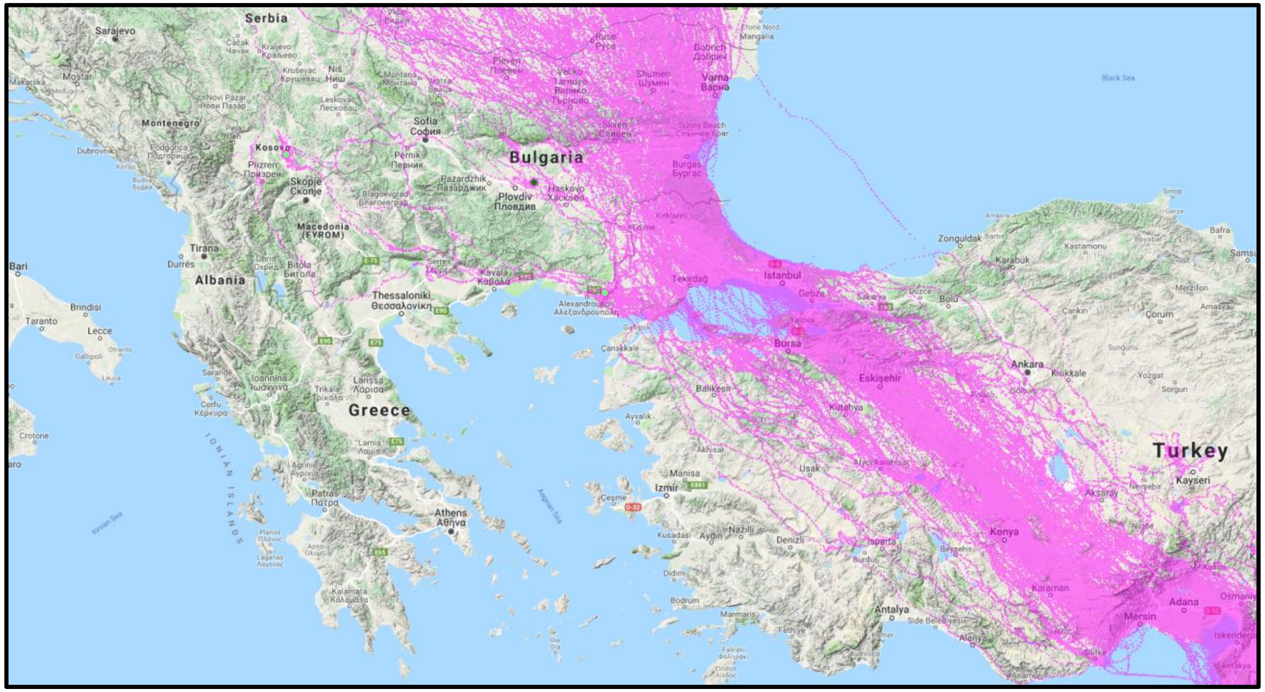
Examples

URL Online databases, such as Movebank (hosted by the Max Planck Institute for Ornithology), act as repositories for animal tracking data. Tracks are owned by the researchers who can be contacted for data requests.

URL The Seabird Tracking Database - Tracking Ocean Wanderers (hosted by BirdLife International) - is the largest collection of seabird tracking data in existence. It serves as a central store for seabird tracking data from around the world and aims to help further seabird conservation work and support the tracking community.

Spatial data

Tracking data (2/2)



Movebank GPS tracking data for White Stork *Ciconia ciconia* showing a migratory bottleneck.

Spatial data

Conservation areas (1/3)

Description Boundaries of areas designated for their conservation importance (protected areas, Natura 2000 sites, Key Biodiversity Areas such as Important Bird and Biodiversity Areas etc.)

Type Polygons / Points

Pros Key areas for consideration when planning renewable energy.

Cons Some datasets costly for commercial use.

Examples

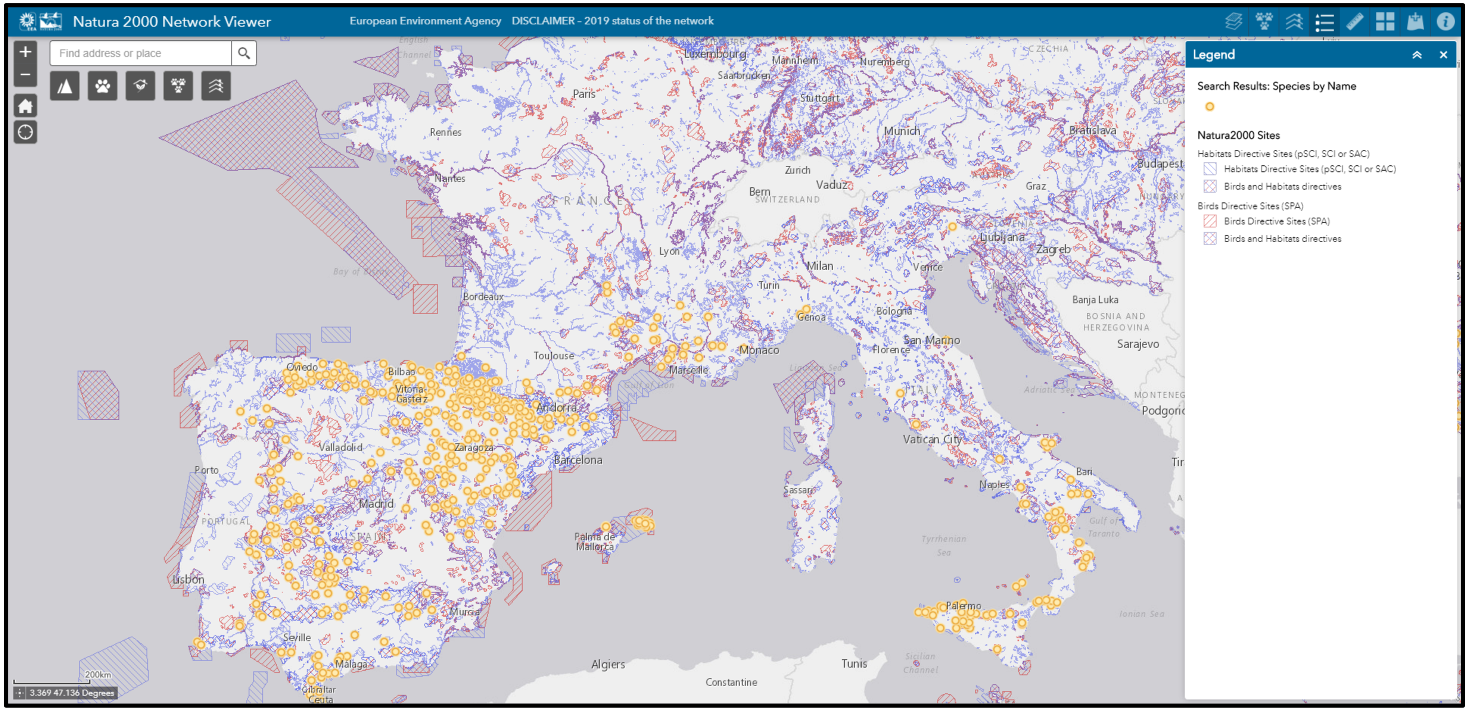
The Natura 2000 network of protected sites in the European Union consists of Special Areas of Conservation (SAC), as defined in the European Union's Habitats Directive (92/43/EEC), and Special Protection Area (SPA), as designated under the European Union Directive on the Conservation of Wild Birds. The Natura 2000 network in turn, is part of the Emerald network of Areas of Special Conservation Interest (ASCIs) under the Bern Convention.

URL The Natura 2000 Viewer is an online tool that presents all Natura 2000 sites, provides key information on the species and habitats for which each site has been designated, as well as population estimates and information on conservation status.

URL Natura 2000 data and maps

Spatial data

Conservation areas (2/3)



Natura 2000 Viewer showing Egyptian Vulture *Neophron percnopterus* SPAs and the site network.

Spatial data

Conservation areas (3/3)

Protected Planet provides extensive, up to date information on protected areas globally. It is managed by the UN Environment World Conservation Monitoring Centre (UNEP-WCMC) with support from IUCN and its World Commission on Protected Areas (WCPA).

Key Biodiversity Areas (KBAs) constitute the largest and most comprehensive global network of sites that are significant for the global persistence of biodiversity. The World Database of KBAs is managed by BirdLife International on behalf of the KBA Partnership. It hosts data on global and regional KBAs, including Important Bird and Biodiversity Areas (IBAs). Additional information on IBAs in the marine realm can be found through the Marine IBA e-Atlas. In the European Union, the IBA inventory has helped inform the designation of Special Protection Areas (SPAs) and its value as a "shadow list" of SPAs has repeatedly been recognised by the European Court of Justice and the European Commission.

For commercial purposes, data from the World Database of Key Biodiversity Areas (KBA) and the World Database on Protected Areas (WDPA) are available through the Integrated Biodiversity Assessment Tool (IBAT).

Ramsar sites: Further details about sites designated under the Ramsar Convention are available, but there is limited availability of spatial data.

Spatial data

Habitat & vegetation (1/2)

Description Depicts ecological communities as they relate to elevation, geology, topography, and soils.

Type Raster / vector

Pros Useful for identifying vulnerable ecological communities.

Cons Maps are often quite general.

Examples

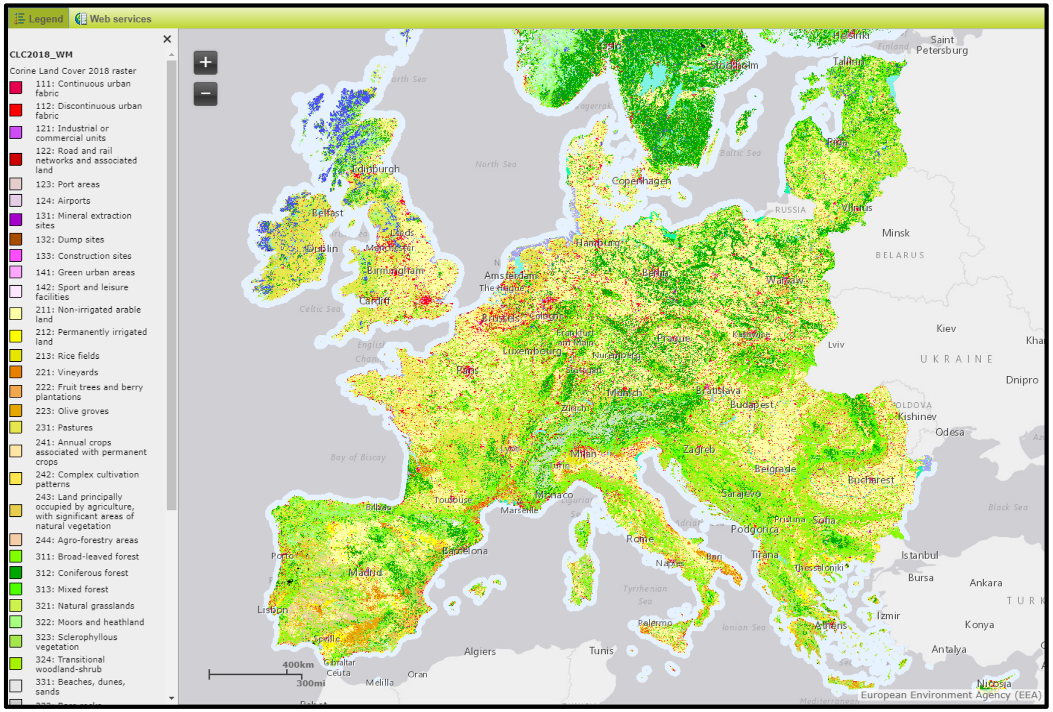
URL Natura 2000 data viewer shows the distribution of habitats reported under Article 17.

URL The CORINE Land Cover (CLC) inventory was established by the European Community as a means of compiling geospatial environmental information in a standardised and comparable manner across the European continent. The programme was initiated in 1985 and the first iteration of the data series covered the reference year of 1990 with subsequent releases covering the years 2000, 2006, 2012, and 2018.

URL The Ocean Data Viewer offers users the opportunity to view and download a range of spatial datasets, including habitat layers, relating to marine and coastal biodiversity.

Spatial data

Habitat & vegetation (2/2)



Corine Land Cover 2018.

Spatial data

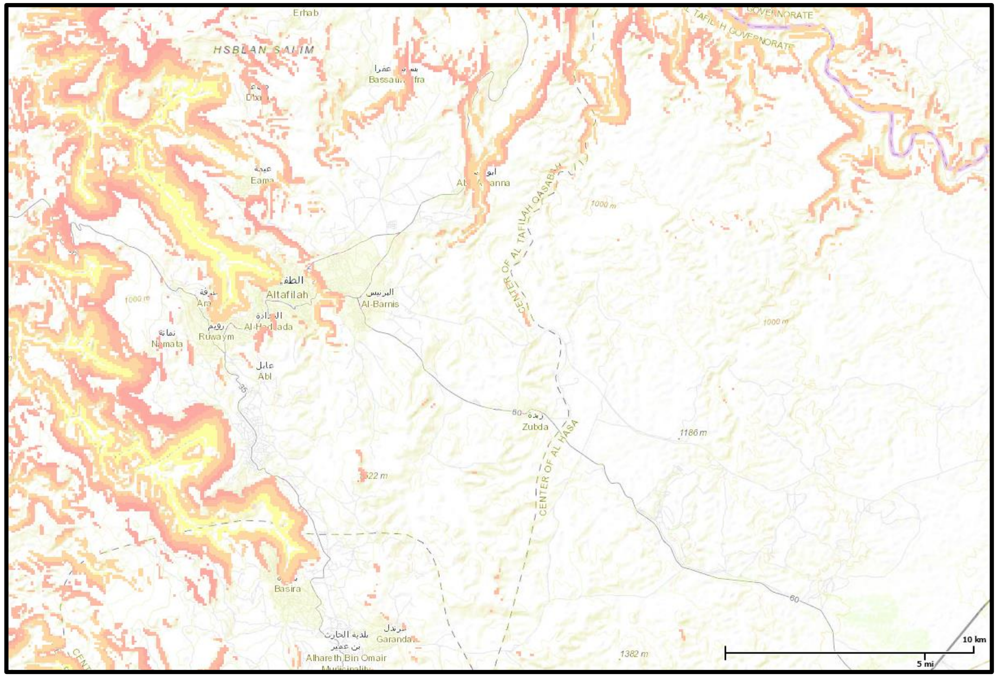
Topography

Description Representation of the shape and features of land surfaces. Topography can be an important factor in the risk associated with renewable energy developments. For instance, certain landscape features, such as cliffs, slopes and ridgelines have been shown to be associated with elevated wind turbine collision risk in soaring bird species (Katzner *et al*. 2012). Cliffs, slopes and ridgelines can be identified by resampling digital elevation models (DEM) such as the ASTER GDEM.

Type Raster / vector

Pros Useful for identifying key landscape features, for instance ridgelines are often associated with the presence of soaring birds.

Cons Can be difficult to interpret in regards to sensitivity.



Extract from the BirdLife International's Soaring Bird Sensitivity Mapping Tool depicting all slopes steeper than 14.5 °.

Spatial data

Resource (1/3)

Description Ideally, wildlife sensitivity maps should be combined with spatial data on renewable energy resource availability (wind, solar radiation, geothermal energy etc.). Doing so enables strategic decisions to be made based on the identification of areas that both offer viable resource potential, but are also not sensitive for wildlife.

Type Raster / vector

Pros Allow for resource availability and environmental sensitivity to be overlaid so as to identify optimal locations for development.

Cons Some datasets are costly for commercial use. There are many additional physical and policy constraints to consider.

Examples

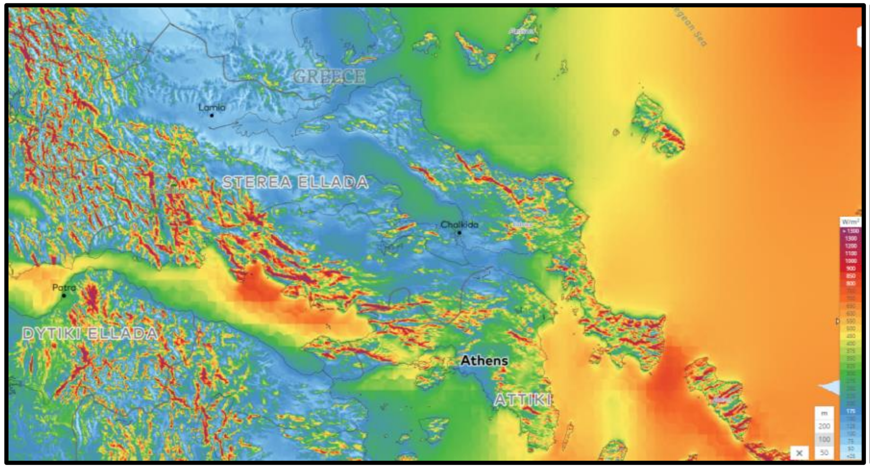
URL The Global Wind Atlas is a free, web-based application developed to help policymakers and investors identify potential high-wind areas for wind power generation virtually anywhere in the world.

URL The Global Solar Atlas supports solar power development in the phases of exploration, prospection, site selection and pre-feasibility evaluation.

URL The Global Atlas for Renewable Energy is a web platform that allows its users to find maps and tools for examining renewable energy resources in locations across the world. Renewable energy sources include Bioenergy, Geothermal, Ocean, Solar and Wind.

Spatial data

Resource (2/3)



TOP: Global Wind Atlas showing wind power density at W/m². BOTTOM: World Solar Atlas showing Global horizontal irradiation (kWh/m²).

URL **IRENA Solar Data Tool** - Ability to show and compare solar radiation time series from different data providers.

URL **SolarGIS** - High resolution solar radiation database developed from Meteosat MSG data, with a web portal.

Spatial data

Resource (3/3)

- Geothermal Atlas - Pan-European Thermal Atlas, heatroadmap. Funded by the EU Horizon 2020 research and innovation programme.
- NOVELTIS - Global and Regional Tidal Current Atlas provides average and time series of tidal velocity.
- Masdar & IRENA Bioenergy Development Simulation Tool.
- Aquatera - global tidal database provides the most comprehensive compilation of tidal data that is currently available.
- AQUARET - Tidal stream resource map for Europe. Co-funded by the European Commission (EU Lifelong Learning Programme Agreement).
- AQUARET - Wave resource distribution for Europe. Co-funded by the European Commission (EU Lifelong Learning Programme Agreement).

Spatial data

Existing installations and transmission (1/2)

Description Where appropriate, wildlife sensitivity maps should incorporate information on electricity networks. In order to assess the cumulative impacts of a renewable energy development it is important to consider any existing energy installations. Given the potential threats associated with power lines it is also important to assess the impact of existing and required transmission infrastructure. Proximity to existing grid infrastructure is also an important consideration when identifying optimal locations for new energy installations.

Type Line

Pros Important for assessing additional and cumulative effects.

Cons Datasets can be difficult or expensive to obtain.

Examples

URL The ENTSO-E Transmission System Map is a comprehensive illustration of the transmission system network (power lines and power plants, including solar and wind) operated by members of the European Network of Transmission System Operators. The map is however only illustrative and does NOT depict real geographic locations.

URL Wind Power is a comprehensive database of detailed raw statistics on wind energy developments through which spatial data on existing sites can be accessed for a fee.

Spatial data

Existing installations and transmission (2/2)

The European Commission maintains a map of projects of common interest (PCIs; namely key cross border infrastructure projects linking the energy systems of EU countries. The PCI viewer map is a transparency platform that provides more information about the PCIs including geographic information, their implementation plan, the benefits they bring to the Member States and the local communities and the Union financial support.

OpenGridMap is an open community that crowdsources realistic power grid data to be used for research purposes. The goal is to create an open platform for inferring realistic power grids based on actual data.

GIS resources and mapping formats

- Wildlife sensitivity mapping with GIS
- Spatial features
- Strengths and weaknesses of GIS
- Examples of available GIS software

GIS resources and mapping formats

Wildlife sensitivity mapping with GIS (1/3)

Geographic Information Systems (GIS) have enabled the rapid development of spatial planning in conservation. In the context of renewable energy development, GIS enables the spatial examination of a range of factors and variables in a single system. These include assessments of resource availability, landscape suitability, habitat type and wildlife distribution and abundance.

GIS-based analysis enables the simple visual representation of sensitivity scores within specified zones across the study site or region. Appropriate areas for sensitivity score calculation can be split up into grids or alternatively successive layers can be scored and overlain based on a common grid, and the output values categorised into classes of sensitivity to generate an overall sensitivity map.

GIS enables the dissemination of spatial data at a variety of levels. Web-based map viewing platforms, such as those powered by ESRI (e.g. through their online platform arcgis.com), are particularly effective at providing an interactive tool for a range of stakeholders to gather information about their specific projects. They can facilitate the initial scoping assessments of developers and output downloadable sensitivity results for subsequent evaluation.

Currently, a range of software packages exist that facilitate GIS assessments:

URL

QGIS is a commonly-used, free and open-source software solution that is relatively user-friendly with the full range of capabilities offered by other commercial packages. It is a realistic option for small NGOs and researchers without institutional backing. It readily integrates a variety of open source tools commonly used to manipulate spatial data, and these include (among others):

GIS resources and mapping formats

Wildlife sensitivity mapping with GIS (2/3)

The Geospatial Data Abstraction Library (GDAL)

GRASS GIS

R is a language and environment for statistical computing and graphics that provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering, etc.) and graphical techniques, and is highly adaptable. R now offers a robust suite of tools paralleling capabilities from standalone spatial GIS solutions by integrating the packages available through QGIS and others. It benefits users by providing a tool that enables a diversity of analyses and transferrable code, thereby enabling repeat analyses across datasets and/ or subsets of datasets. Furthermore, code can be sourced from numerous online help fora, providing a substantial support community for users. However, R is a programming language that does require familiarity with coding, hence it requires more initial training than some other solutions.

The commercial products ArcGIS and MapInfo are also commonly used. They are the traditional software packages that have been used by ecologists, and have benefitted from significant developments over time. These enhancements have resulted in relatively streamlined and intuitive software, with well-developed online help menus.

ArcGIS is developed by the Environmental Systems Research Institute (ESRI). The cost of licenses varies in accordance with intended usage and with capabilities, and is relatively inexpensive for students, non-profit organisations and others

GIS resources and mapping formats

Wildlife sensitivity mapping with GIS (3/3)

intending to use the software for non-commercial application.

MapInfo is developed by Pitney Bowes Software (formerly MapInfo Corporation). The costs vary with intended usage.

GIS resources and mapping formats

Spatial features

There are three different types of feature mapping with GIS: **points**, **lines** and **polygons**. Points represent precise coordinate locations. While points illustrate the general location, typically the centroid, they do not reflect extent, e.g. the size of a breeding colony or a bat roost. Lines represent linear features in the environment, such as roads or rivers. They reflect linear extent but like points, they do not reflect extent of area. Lastly, polygons represent areas such as the boundary of a protected area.

Spatial layers are traditionally displayed in one of two formats, either raster (an array of cells holding a single value characterizing all of that cell's area) or vector (a series of points, lines and polygons with each element having unique identifiers that link to geographic elements of the attribute data). An outline of the differences in these data forms is shown in the Table.

Vector	Raster
Feature-oriented	Space-orientated
Efficient storage of boundaries only	Data-intensive
"Maplike"	"Image-like"
Geometry of spatial relationships is complex	Simple relational geometry
Network analysis	Numerous spatial analyses
Strong in database query	Strong in analysis of continuous data

Features of Vector and Raster data (SOURCE Eastman 1995)

GIS resources and mapping formats

Strengths and weaknesses of GIS

Strengths

- Free, Open-Source platforms are available that support **viewing editing and analysis of geospatial data**.
- Data can be shared electronically and maps can be reproduced (most easily done by producing a map package).
- A large amount of remote sensing landscape-scale data is freely available online where it is continually updated.
- Outputs can be displayed in web-based interactive viewers for non-specialist and public consumption. Online maps can be easily interpreted and be accompanied by downloadable outputs.
- An excellent scoping tool for regional planning, as well as an informative tool for preliminary site assessment.
- A powerful tool for mapping individual animal movements that can be used to inform estimations of population level threats (e.g. flight patterns and height of birds around wind farms).
- Stacking successive layers of spatial data permits the creation of sensitivity scores for certain grid squares in a region.

Weaknesses

- Licenced software for some of the packages can be expensive.
- Staff require considerable training and specialists may be required for complex analyses.
- Open-Source platforms can be less stable.
- Switching between GIS platforms requires a level of retraining and adjustment.
- Use of this technology in the field may be limited by the lack of, or limited access to, the internet.

GIS resources and mapping formats

Examples of available GIS software

Commercial

- CartoDB
- ESRI ArcMap /ArcGIS Online
- GeoMedia
- Global Mapper 20
- Golden Software's MapViewer or Surfer
- MangoMap
- Manifold
- MAPINFO
- TerrSet (IDRISI)

Open source

- Google Earth Engine
- GRASS GIS
- gvSIG
- MapServer
- MapWindow
- OpenGeo Suite
- OpenJUMP
- uDig
- SAGA GIS
- SuperGIS Desktop
- QGIS

Glossary, references and acknowledgements

- Glossary
- References
- Acknowledgements

Glossary, references and acknowledgements

Glossary (1/12)

Appropriate Assessment The Birds and Habitats Directives set out various procedures and obligations in relation to nature conservation management in Member States in general, and of the Natura 2000 sites and their habitats and species in particular. A key protection mechanism is the requirement to consider the possible nature conservation implications of any plan or project on the Natura 2000 site network before any decision is made to allow that plan or project to proceed. When being considered for approval at any stage, each plan or project must take into consideration the possible effects it may have in combination with other plans and projects when going through the process known as "Appropriate Assessment".

Atlas There are many biodiversity datasets available in Atlas format. Atlases are snapshot surveys undertaken to capture presence or absence of a species within a region, country or at a wider scale, and usually based on a pre-defined grid. For example, the last European Atlas of Breeding Birds was based on a 50-km grid.

Article 12 (Birds Directive) Article 12 of the Birds Directive requires Member States to report about the progress made with the implementation of the Birds Directive.

Article 17 (Habitats Directive) Article 17 of the Habitats Directive requires Member States to report about the progress made with the implementation of the Habitats Directive.

Barrier effects Term used to explain where movements, such as foraging or migratory flights are affected and occasionally precluded by the location of a development. This effectively results in habitat fragmentation and can place additional energetic demands on those individuals affected.

Glossary, references and acknowledgements

Glossary (2/12)

Biodiversity Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

Biodiversity data Data largely from surveys that are used to inform the distribution of the species that are included in the sensitivity maps. These data are mostly point locations reflecting sightings, nests, roosts etc. Occasionally range data (polygon format) or data contained at transect level (line format) are used.

Barotrauma tissue damage to air-containing structures caused by rapid or excessive pressure change; pulmonary barotrauma is lung damage due to expansion of air in the lungs that is not accommodated by exhalation. The decompression hypothesis proposes that bats are killed by barotrauma caused by rapid air-pressure reduction near moving turbine blades.

Climate change Climate itself can be described as the average weather over a prolonged period. Therefore, climate change refers to a significant perturbation in the elements comprising climate, such as temperature, rainfall, or wind, lasting for an extended period – decades or longer. Crucially, during this epoch, human activities are significantly perturbing the natural cycle of glacial and interglacial intervals through excessive addition of greenhouse gases to the atmosphere. This interference is resulting in increased air and ocean temperatures, drought, melting ice and snow, rising sea levels, increased rainfall, flooding and other influences.

Collision mortality Caused when an animal accidentally hits, and is killed by, a renewable energy device when moving. Non-lethal collisions also occur and present a dilemma for post-construction monitoring when crippled individuals depart the

Glossary, references and acknowledgements

Glossary (3/12)

immediate vicinity.

Collision risk Assessment of the likelihood of direct collision between a species and a renewable device. Usually presented as a broadscale likelihood factor (e.g. high, medium, low, very low) based on scores generated from an assessment of morphological traits and habitat use.

Collision Risk Modelling A modelling technique that can be carried out with one of various methodologies including the Band model, Tucker kinematic model, Hamer model, Biosis model and Hamer model etc.

Constraints mapping Identification and mapping of the limitations and restrictions to renewable energy development (based on economic, cultural or environmental activities and features) carried out in order to gain an accurate and realistic estimation of potential land available.

CORINE The CORINE (Co-ORdinated INformation on the Environment) data series was established by the European Community (EC) as a means of compiling geo-spatial environmental information in a standardised and comparable manner across the European continent. The first iteration of the data series covered the reference year of 1990 with subsequent releases covering the years 2000, 2006, 2012 and 2018.

Data portal Online platform making datasets accessible and available.

Density Surface Modelling A DSM can be used to predict abundance over a larger/different area than was originally surveyed.

Glossary, references and acknowledgements

Glossary (4/12)

DSMs allocate observations of animals to segments of line (or strip transects) and adjusts the counts based on detectability using a supplied detection function model. A generalized additive model, generalized mixed model or generalized linear model is then used to model these adjusted counts based on a formula involving environmental covariates.

Development footprint Defines the overall area that affects the distribution of all impacted species. This is often larger than the immediate vicinity of the technology due to wider impacts, such as those caused by habitat loss during construction, and/ or barrier effects for example.

Displacement Where disturbance events, such as those caused by construction and operation of renewable energy projects, cause abandonment of an area by certain species, thereby altering their distribution and available habitat. Some species are less tolerant of disturbance and will have a higher propensity for displacement.

Distance sampling Generally, the probability of detecting an individual decreases with increasing distance from the observer, and distance sampling is based on detection functions, which model the probability of detecting an individual, given its distance from the transect. This concept is fundamental to the development of Density Surface Models detailed above.

EIA Directive The aim of the current EIA Directive (2011/92/EU), as amended by Directive 2014/52/EU is to ensure a high level of protection of the environment through the establishment of minimum requirements for environmental impact assessment (EIA) prior to the development consent being given. The purpose is to provide the competent authority with a full account of likely environmental impacts.

Glossary, references and acknowledgements

Glossary (5/12)

Environmental Impact Assessments (EIAs) Environmental Impact Assessment (EIA) is the process of examining the anticipated environmental effects of a proposed project, from consideration of environmental aspects at design stage, through consultation and preparation of an Environmental Impact Assessment Report (EIAR), evaluation of the EIAR by a competent authority and the subsequent decision as to whether the project should be permitted to proceed, encompassing public response to that decision. An EIAR is a report or statement of the effects, if any, which the proposed project, if carried out, would have on the environment. It is prepared by the developer to inform the EIA process.

ESAS (European Seabirds At Sea) The European Seabirds at Sea (ESAS) database is a collaborative partnership between the Joint Nature Conservation Committee (JNCC) and seabird researchers in north-west Europe. Approximately 3 million counts of seabirds have been collected from at-sea surveys from ships and aircraft since 1979 following standardised methods. The resulting database is managed by the JNCC on behalf of the ESAS Co-ordinating Group.

EU Birds Directive The Birds Directive (Directive 2009/147/EC on the conservation of wild birds), first adopted by the Member States in 1979, is the European Union's oldest piece of nature legislation that aims to protect all of the 500 wild bird species naturally occurring in the European Union. The directive also provides a system for the management of the hunting (including falconry) of those bird listed in Annex II.

EU Habitats Directive Adopted in 1992, the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right.

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EU Renewable Energy Directive The EU Renewable Energy Directive (2009/28/EC) provides a policy for the production and promotion of energy from renewable sources in the EU.

Flyway The term flyway defines the entire range of a migratory bird species (or groups of related species or distinct populations of a single species) through which it moves on an annual basis from the breeding grounds to non-breeding areas, including intermediate resting and feeding places as well as the area within which the birds migrate.

Geographic Information Systems (GIS) A geographic information system (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present all types of spatial data.

Global Positioning System (GPS) GPS is a radio navigation system that allows land, sea, and airborne users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world.

Geospatial data The data or information that identify the geographic location of features and boundaries on Earth. Geospatial data are usually stored as coordinates and topology, and are data that can be mapped.

Geothermal energy Geothermal energy is the process of extracting the heat from the Earth. Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of magma.

Home Range An estimation of the area that a species occupies in the landscape. This can be examined at the core (50%) and

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overall (100%) level to understand where overlap between species' movements and developments may occur and therefore potential conflict zones.

IBAT: Integrated Biodiversity Assessment Tool IBAT helps businesses incorporate biodiversity considerations into key project planning and management decisions.

Important Bird and Biodiversity Area An Important Bird and Biodiversity Area (IBA) is an area identified using an internationally agreed set of criteria as being globally important for the conservation of bird populations. IBAs were developed and identified by BirdLife International. Currently, there are over 13,000 IBAs worldwide.

Map unit This refers to the mapping scale, which is broadly variable, and tends to vary in accordance with the size of the region being covered, and/ or the resolution of the survey data included.

Mitigation In relation to energy development, this refers to the process of correcting any developments and structures that present a hazard to wildlife. Mitigation is best implemented in accordance with the mitigation hierarchy of avoid, minimise, restore or rehabilitate and finally offset or, failing that, compensate.

Morphological trait Physical characteristics of species that may make them more susceptible to collision or electrocution. For example, wing loading (ratio of weight to wing area) and aspect ratio (i.e. ratio of wingspan squared to wing area) can be used to broadly classify species into vulnerability categories but these details should be considered in context with other site-specific and behavioural factors.

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Natura 2000 Natura 2000 is a network of nature protection areas in the territory of the EU. It is made up of Special Areas of Conservation and Special Protection Areas designated respectively under the Habitats Directive and Birds Directive. The network includes both terrestrial and marine sites.

Offshore Technology Referring to all renewable developments taking place in the marine environment.

Onshore Technology Referring to all renewable developments taking place on land, above the high water mark.

Pentad An example of a grid used in sensitivity mapping whereby the scale of each square represents 5 minutes of latitude by 5 minutes of longitude.

Planning Planning has a fundamental influence on future energy use through both ensuring that future planned development, of all kinds, anticipates transition to the most efficient energy technologies, infrastructure and modes of use and through facilitating sustainable development of the renewable energy sector.

Population Viability Analysis An assessment of extinction risk for a species whereby simulations of deterministic forces, as well as demographic, environmental and genetic stochastic events can be applied to a population to determine its likelihood of persistence over a given period.

Regression modelling Regression models are used to develop Species Distribution Models, which estimate the relationship between species records at sites and the environmental and/or spatial characteristics at those sites, where species data have

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been collected systematically, e.g. in formal biological surveys in which a set of sites are surveyed and the presence/ absence or abundance of species at each site are recorded.

Resolution (mapping) Refer to map unit above.

Roost Typically, a roost refers to a site regularly used by birds or bats for shelter. Several species of bird (e.g. wildfowl, waders and starlings) congregate in large flocks to rest and the sites are consistently used each season. Bats require different roosting conditions throughout the year and will often relocate to find an appropriate roost. For several weeks in summer, female bats gather in a maternity roost, while in winter, bats use hibernation roosts.

Topography Topography is a broad term used to describe the detailed study of the Earth's surface. This includes deviations from the planar surface, such as mountains and valleys, as well as features, such as rivers and roads.

Transect An ecological sampling unit often used during biodiversity surveys or mortality monitoring (e.g. strip transects at sea).

Sensitivity score Scores generated for each species of interest, which take into account the morphological traits, habitat requirements and conservation status that may render them susceptible to adverse impacts of the development. These scores are then applied to the mapping grid and summed across the species of interest, generating a heatmap reflecting sensitivity.

Site selection Site selection usually involves some GIS analyses that identify areas suitable for development (based on the availability of the renewable resource), while taking into consideration factors that could minimise the negative impacts on

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biodiversity, as well as a variety of constraints driven principally by social, economic and environmental factors.

Solar energy The process of extracting energy from solar radiation. There are currently two types of solar power technology. Photovoltaic (PV) systems convert solar radiation directly to electricity by exposing solar cells to incoming radiation. Concentrated Solar Power systems generate solar power by using reflective surfaces to concentrate a large area of sunlight into a receiver (presenting potential hazards for overflying wildlife).

Spatial data The data or information that identify the geographic location of features and boundaries on Earth. Spatial data are usually stored as coordinates and topology, and are data that can be mapped.

Special Areas of Conservation (SACs) A Special Area of Conservation (SAC) is defined in the EU Habitats Directive (92/43/EEC), also known as the Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora. They are to protect the habitats and species listed in Annex I and II of the directive, which are considered to be of European interest following criteria given in the directive.

Special Protection Areas (SPAs) A Special Protection Area (SPA) is a designation under the EU Directive on the Conservation of Wild Birds. Under the Directive, Member States have a duty to safeguard the habitats of migratory birds and certain particularly threatened birds.

Species Distribution Model (SDM) Species Distribution Models (SDMs) are used to model complete distributions, including in unsampled locations. They are useful where survey data tend to be sparse and/or limited in coverage.

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Strategic Environmental Assessment (SEA) Strategic Environmental Assessment (SEA) is the process by which environmental considerations are required to be fully integrated into the preparation of plans and programmes prior to their final adoption. The objectives of SEAs are to provide for a high level of protection of the environment and to promote sustainable development.

Tidal energy Tidal energy is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. A common model for tidal power facilities has involved situating a tidal dam, or barrage, with a sluice across a narrow bay or estuary. As the tide flows in or out, creating uneven water levels on either side of the barrage, the sluice is opened and water flows through low-head hydro turbines to generate electricity. Other models for tidal facilities are being developed, including tidal lagoons, tidal fences and underwater tidal turbines.

Ramsar The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention.

Raster A raster map is an electronic map image made up of a set number of pixels. Unlike vector mapping, the data cannot be manipulated. The geographic location of each cell is implied by its position in the cell matrix. Accordingly, no geographic coordinates are stored. Due to the nature of the data storage technique data analysis is usually easy to program and quick to perform. Many environmental datasets are produced in raster format.

Renewable energy Energy generated through renewable sources, principally wind, solar, geothermal, tidal or wave energy.

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Vector data Vector data are split into three types: polygon, line and point data. Polygons are used to represent areas such as the boundary of a city (on a large-scale map), lake, or forest. Lines are used to represent linear features. Common examples are rivers, roads, and transects. Line features only have one dimension and therefore can only be used to measure length. Point represent nonadjacent features and discrete data points. They have zero dimensions; therefore, you can measure neither length nor area with this dataset.

Wave energy Wave energy extraction capitalises on the rise and fall of coastal waters. This energy is extracted through a diverse range of floating, submerged and shoreline devices.

Wind energy Wind is the dominant contributor to renewable energy production, accounting for 18% of the EU's total electricity generation capacity (2019). Wind energy is typically extracted through three-bladed horizontal-axis wind turbines.

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