CWW 2023

BOOK OF ABSTRACTS

Šibenik

Nature inclusive upscaling of wind energy

Croatia

18-22 September 2023

Conference on Wind energy and Wildlife impacts

Organizers

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Welcome to the 7th Conference on Wind Energy and Wildlife Impacts – CWW 2023, organised under the patronage of the European Parliament.

The scientific program of the conference, centred around the theme of "Nature inclusive upscaling of wind energy", encompasses three keynote speeches, two panel discussions, six workshops, four special sessions, 108 oral presentations, and nearly 90 poster presentations.

The abstracts featured in this book showcase the highest achievements in the field and are intended to start productive discussions and contribute to finding innovative solutions to prevent, minimize, and mitigate the impacts of wind farms on wildlife.

While we have aimed to compile as complete a book of abstracts as possible, some talks and sessions were in the final stages of planning when we drafted this book of abstracts, and therefore some details may be missing or may be slightly inaccurate for those talks/sessions.
We trust that you will discover both the abstracts and the conference at large to be insightful and inspiring.

With warm regards,

Dalibor Hatić,
Chair Organizing Committee,
Oikon Ltd. – Institute of Applied Ecology

Mirna Mazija,
Co-chair Organizing Committee,
Supernatural Ltd.

David Tidhar,
Chair Scientific Advisory Committee,
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KEYNOTES

REGULATING CLIMATE FOR NATURE VERSUS REGULATING NATURE FOR CLIMATE

Johann Köppel, *Technical University Berlin/Uppsala University, Campus Gotland and*
Roel May, *Norwegian Institute for Nature Research*

For more than a decade, the CWW community has presented the current state of knowledge and perspectives on wind energy's wildlife implications. Rarely have we seen such a targeted joined effort to bring science on the agenda of developers and regulators. Over the very same time span, our globe faced the hottest years since systematic monitoring, and wildfires and floods accompany our pathways to Croatia. Simultaneously, massive upscaling of wind energy is on the forefront. Thus, how can we ensure to provide knowledge and tools to keep the wind energy and wildlife science – policy – practice gap as close as possible? Have we truly embraced our shared responsibility for both nature and climate? With a set of relevant hypotheses and questions, we wish to provide food for thought to reflect on during the conference, its closing session and in its aftermath.

TOWARDS SOLVING THE GLOBAL WIND ENERGY-BAT CONFLICT: CURRENT STATE AND FUTURE PERSPECTIVES

Christian C. Voigt, *Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany*
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Wind energy production is growing rapidly around the world in an effort to reduce greenhouse gas emissions. However, wind energy production is not environmentally neutral and efforts must be made to reconcile the environmental goals of protecting our climate and our biodiversity. Using bats as an example, I will review the state of knowledge on the conflict between wind energy production and bats in Europe and worldwide. I will identify obvious and hidden problems, point out concrete solutions, highlight gaps in our knowledge and formulate perspectives that will help solve an important green-green dilemma.

THE FUTURE OF CWW

David Tidhar[1], Aonghais Cook[2], Branko Karapandža[3], Cris Hein[4], Dalibor Hatić[5], Đuro Huber[5], Ed Arnett[6], Emma Bennett[7], Johann Köppel[8,9], Kate Williams[10], Laith El-Moghrabi[11], Mirna Mazija[12], Roel May[13], Sytske van den Akker[14], Winifred F. Frick[15], Wouter Lengkeek[16]
[1]Masdar, [2]British Trust for Ornithology, [3]Fauna C&M, [4]National Renewable Energy Laboratory (NREL), [5]Oikon Ltd. – Institute of Applied Ecology, [6]The Wildlife Society, [7]Monash University, [8]Technische Universität Berlin, [9]Uppsala University, Campus Gotland, [10]Biodiversity Research Institute, [11]Fieldfare Ecology, [12]Supernatural Ltd., [13]Norwegian Institute for Nature Research, [14]Vattenfall, [15]Bat Conservation International, [16]Waardenburg Ecology
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The Conference on Wind Energy and Wildlife (CWW) has reached an important milestone in this, it's seventh event. The 7th CWW has exceeded well over 500 in person attendees from over 30 countries, attracting nearly 200 abstract submissions from leading researchers, consultants, stakeholders, industry representatives, project developers and owner-operators, students, regulators, and others. CWW is unusual in that it has no formal organization and all the conferences to-date have been initiated and developed by an iterative group united in a shared vision in the value of this knowledge sharing and networking event. In this presentation, the current Chair of the CWW Scientific Advisory Committee will present some of the key challenges and risks to CWW, discuss the SAC's strategy for CWW in the foreseeable future, and invite the audience – the CWW community – to offer their ideas, so that together we can ensure the future success of CWW.

INCREASING CONNECTION AND LEARNINGS IN THE INTERNATIONAL STUDY OF WIND ENERGY AND WILDLIFE

Taber D. Allison[1], *[1]Renewable Energy Wildlife Institute, 20005, Washington, DC, United States*
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In Europe and the U.S., researchers in wind energy and wildlife regularly gather to share the latest scientific results to better understand the risk of on and offshore wind energy to wildlife and how to mitigate that risk. Despite important differences in the natural and regulatory environment, common themes have emerged. These themes have informed what we know and have influenced how we manage the necessary growth of wind energy to mitigate the great risk of global climate warming to wildlife while simultaneously minimizing the risks of that growth to wildlife. In the U.S., the bi-annual Wind-Wildlife Research Meeting (WWRM) has alternated with the Conference on Wind Energy and Wildlife. The two meetings attract largely different audiences, but there is an overlap in participation and presentation of research from both sides of the Atlantic in the different meetings. Organizers of both meetings realize that the potential connections between the two meetings could be improved, and there is an opportunity to carry over themes and research outcomes from one meeting to the next. In this presentation, I will describe major themes that have emerged from the most recent WWRM meetings, integrate those with the themes of the recent CWW meetings, and propose recommendations for how the two meetings moving forward, can build on and continue our work.

Key words: wind-wildlife science, mitigation, communication, technology

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WORKSHOPS

A LAUNCHING AND TRAINING (WITH IN-FIELD COMPONENT) OF THE GOOD PRACTICE HANDBOOK ON POST-CONSTRUCTION FATALITY MONITORING (PCFM) FOR ONSHORE WIND PROJECTS IN EMERGING MARKETS AND ITS AUTOMATED DECISION SUPPORT TOOL

David Tidhar[1], Paul Rabie[2], Kate MacEwan[2], Zoe Howell[3], Lori Anna Conzo[4], Robert Adamcyzk[5]

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The impacts associated with onshore wind energy facilities (WEFs) are highly unpredictable, even when robust pre-construction baseline survey results are available (Ferrer et al. 2012; Hein, Gruver, and Arnett 2013; Solick et al. 2020). Although rigorous pre-construction baseline studies are necessary to characterize risks, post-construction fatality monitoring (PCFM) is the only way to understand the actual collision impacts of WEFs on birds and bats. Implementing a robust PCFM program during the operational phase of a WEF is therefore critical for effective management and mitigation of biodiversity impacts. A soon-to-be published PCFM Handbook and Decision Support Tool has been developed by the International Finance Corporation (IFC), the European Bank for Reconstruction and Development (EBRD) and Kreditanstalt Für Wiederaufbau (KfW), with the core aim of providing a resource that develops and consolidates PCFM good practice for use in emerging market countries and elsewhere. Attendees of this all-day workshop will receive training in the design and implementation of PCFM, including: a) introduction to all of the primary aspects of PCFM; b) detailed overview of the Handbook, and key supporting tools to assist in the monitoring design; c) overview of key analysis tools, including GenEst; d) introduction and practice of the main field elements of PCFM, and; e) insights on avoiding and dealing with common implementation challenges.

COLLISION RISK MODELS AT 40: CURRENT STATUS AND APPROACHES TO IMPROVE GLOBAL COORDINATION AND UTILITY

Kate Williams[1], Evan Adams[4], Andrew Gilbert[4], Aonghais Cook[2], Pamela Loring[3]
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The first collision risk model (CRM) was published in 1983. Forty years later, we will identify key avenues to continue improving CRMs for use in terrestrial and marine contexts worldwide. The goals of the workshop will be to (1) Review different CRM approaches around the globe, (2) Discuss emerging topics, including integrating different data types/taxa/life history stages into density models and developing better frameworks for estimating cumulative impacts with CRMs, and (3) Identify interest in developing a global working group focused on these issues. The first half of the agenda will include presentations and panel discussion on the current state of the science, focusing on scientific priorities for making CRMs more useful and broadly applicable and on key challenges for implementing CRMs in a global context. Presentations will include: (1) Review of the types of CRMs in current use (Aonghais Cook, BTO), (2) Using movement data to predict collision risk for endangered shorebird and seabird species in the U.S. Atlantic (Andrew Gilbert/Evan Adams, BRI), (3) An individual-based CRM for lesser black-backed gulls (Floor Soudijn, Wageningen Marine Research), and (4) StochLab R package and RShiny interfaces for creating and running CRMs (Grant Humphries, BlackBawks Data Science). The second half of the workshop will consist of small group discussions, followed by a final full group discussion on the potential development of a global working group focused on CRM issues. Breakout group discussions will address questions such as: (1) What does a "good" CRM look like (e.g., transparency, freely available code/software, clearly defined input parameters, sensitivity analysis)? (2) What are the minimum data requirements for CRMs? (3) How do we more effectively structure CRMs to allow for estimation of effects across projects over time (e.g., to address cumulative effects questions)? (4) How can/should the results of CRMs be used in a regulatory context, including in emerging markets, and how can we get further regulatory input on this question? and (5) Are there standards, guidelines, or other products that could be developed to help to facilitate the use of scientifically appropriate CRMs around the world? By the end of the workshop, we will have identified a preliminary list of working group members, gathered a range of ideas on further development and implementation of CRMs, and started to develop a workplan to pursue workgroup funding and align the group with existing initiatives such as the Convention on Migratory Species (CMS) Energy Task Force.

Key words: collision risk model, standards, cumulative effects, offshore, land-based

The Shutdown on Demand Workshop features the following two abstracts:

HOW MUCH IS SHUTDOWN ON DEMAND THE SOLUTION FOR BIRD MORTALITY AT WIND FARMS?

Ricardo Tomé[1], Filipe Canário[1], David Wilson[1]

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Shutdown on Demand (SDOD) is considered the most effective mitigation measure for reducing bird collision risk at wind farms, and consists of shutting down turbines temporarily in response to the presence of species of concern or high numbers of individuals at risk. SDOD can be observer-assisted, technology-assisted (i.e., using radar or camera detection) or a combination of both. This method has been applied in different geographies, and targeting different groups of birds (e.g. migrating and resident raptors, migrating passerines), and available results indicate that mortality rates of target species can be reduced between 50% to close to 100% with very low impacts on energy production (generally < 0.5%). Nevertheless, the application of this method can be quite challenging and many questions remain, especially as wind projects expand into new areas: How can we predict production losses from SDOD in the planning or permitting phases? How can SDOD be operated offshore or in wind farms placed in remote locations, where there are no field observers available and/or where technologies are less effective or difficult to deploy? How to choose between observers and technology (or a mix of both)? Is SDOD feasible in very large-scale wind-farms, occupying areas of thousands of km2? Losses in production seem to be negligible, but what about operation costs? How to monitor SDOD performance? How can we define shutdown criteria and mortality thresholds? Should SDOD allow for permitting under any circumstances? Hoping to promote a comprehensive discussion between researchers, consultants, developers, lenders and regulators, we propose to organize a four-step interactive workshop on SDOD, comprising: i) An initial presentation reviewing and presenting the state-of-the-art results from SDOD operation and addressing main present and future challenges; ii) Discussion in small groups, addressing the main topics involving SDOD; iii) Presentation of main conclusions from each group; iv) Wrap-up general conclusions and recommendations. We expect the workshop to last for 2h (step 1 – 15 min; step 2 – 40 min; step 3 – 40 min; step 4 – 25 min); c. 40 people are expected to attend.

Key words: Shutdown On Demand, mitigation, mortality, efficiency, birds

THE ATMP CONSTRAINTS AND SOLUTIONS: GOOD INTERNATIONAL INDUSTRY PRACTICES

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Egypt is one of the main crossroads for soaring birds migrating from breeding grounds in Europe and Asia to wintering areas in Africa, of particular concern, the Gulf of Suez lays on the heart of the migration flyway for soaring birds, where majority of flyway populations cross the area during spring and autumn migrations. In this regard, the Regional Centre of Renewable Energy and Energy Efficiency (RCREEE) launched the first of its kind strategic and operational program evaluating environmental impacts and monitoring soaring birds' migration in Egypt entitled 'Active Turbine Management Program' (ATMP). The ATMP is a global flagship effort taking place in the Gulf of Suez region in Egypt, which is undertaken through a joint protocol between RCREEE, the Egyptian Environmental Affairs Agency (EEAA), the Egyptian Electrical Transmission Company (EETC) and New and Renewable Energy Authority (NREA). Thus, this study will address the fact that the ATMP trusts that in order to adequately address cumulative effects on biodiversity from wind power projects for more than 3,000 MW wind projects, a coordinated approach at the national level represents good practice. Therefore, to ensure that the expansion of the wind energy sector does not compromise priority biodiversity values, practitioners, regulators and lenders will need to regularize the management of biodiversity risk through the following measures: a Collective Bird Monitoring Program (BMP), a Predictive Fixed Shutdown Program (PFS-Program), Shutdown on Demand Program (SOD-Program), and a Fatality Monitoring Program (FMP). With that, despite the various constraints the ATMP has dealt with (during both pre- and post- construction phases) the ATMP is deemed to be a technical, financial and environmental solution for lenders, investors, government authorities, environmental experts, etc. Additionally, the ATMP can be considered as one of the good examples of best international industry practices through its solution.
Key words: ATMP, Innovative Solutions, Lessons Learnt

DEALING WITH UNCERTAINTY – PARTICIPATORY IDENTIFICATION OF LEVERAGE THRESHOLDS FOR IMPACTS

Roel May[1], Miguel Mascarenhas[2], Cris Hein[3]
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The expansion of wind energy poses challenges to policy- and decision-makers to address necessary carbon reduction goals while limiting conflicts with wildlife. Environmental impact assessments are used to ensure that the potential environmental consequences of plans and projects are considered before the project is licensed. Based on these, decision-makers need to balance the potential environmental cost with the socio-economic benefits. However, what if the likelihood or magnitude of an impact is uncertain due to lack of knowledge on the species or ecosystem, limited available data, or validity of statistical models? Conflicts may arise when there are discrepancies between what is deemed 'good enough' and 'acceptable', and are often associated with difficulties of prediction where impacts are subject to considerable uncertainty. This requires decision-makers to deal with different sources of uncertainty: natural stochasticity, statistical variance, social doubt, technical inefficiency, and indecisiveness. Still, we must work with the best available knowledge, and act to the best of our ability. In addition to this, decision-makers must also deal with social issues and an increasingly polarized society, not only technical uncertainty but also intolerance and a lack of space for the much-needed collective reflection required for decision-making in the face of uncertainty. Uncertainty will always be here; it is crucial that, as a species and collectively, we know how to cope with it. Aim: This workshop aims to take up these different dimensions of uncertainty and allows the participants interactively discuss what defines these, and how to improve setting appropriate thresholds in the face of uncertainty. Form: The workshop will be introduced by several invited speakers illustrating different perspectives of uncertainty. Thereafter, using an interactive Delphi design (online survey, mind-mapping, SWOT) participants will discuss how 'dealing with uncertainty' can best be pursued and which leverage thresholds may be best to support sustainable decision-making. Proposed invited speakers and panel (not contacted yet): • Liz Masden (UHI) [ecological perspective] • Paul Rabie (WEST) [statistical perspective] • Gesa Geißler (BOKU) [planning perspective] • Regulator [decision perspective] • Development bank [financial perspective] • Industry [practice perspective]

Key words: uncertainty, impact thresholds, acceptable

MODELLING FUTURE WIND ENERGY BUILD OUT TO UNDERSTAND EMERGING CONSERVATION AND SOCIAL CHALLENGES. CAN IT BE DONE IN YOUR COUNTRY?

Jay Diffendorfer[1], Anthony Lopez[2], Bethany Straw[3], Trieu Mai[2], Charles Labuzzetta[4], Ashton Wiens[5]

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Goal. Can we achieve deep decarbonization without negatively impacting wildlife? What effect would broad-scale turbine curtailment or strict local siting regulations have on national energy strategies and electricity prices? This workshop focuses on understanding the ecological and social challenges associated with expanding wind energy. Methods and tools exist to site new wind energy and reduce impacts to wildlife. However, few approaches can forecast detailed wind turbine development and link this to environmental information so that bi-directional analysis can occur. For example, how will future wind energy impact a species AND how will species conservation measures constrain development? The workshop will describe one approach to consider wind energy futures and ask participants to frame how they could address similar questions in other parts of the world. Materials and Methods. In the first 30 minutes, we will describe an approach developed by a U.S. multi-agency, interdisciplinary working group that integrates energy development forecasting, social and environmental constraints, bat fatality modelling, and the BatTool - a generalizable bat population demography model. We introduce the National Renewable Energy Laboratories (NREL) Renewable Energy Potential/ Regional Energy Deployment System (reV/ReEDS) models, describing inputs, outputs, and key processes. These open-source models simulate the electric sector, the spatial distribution of wind turbines, and have been used to investigate how technology, social opposition, and transmission choices affect wind development. We then explain the integration of environmental constraints on wind deployment into reV/ReEDS to study 1) interactions between conservation and national decarbonization strategies and 2) future wind energy impacts on bats by linking future turbine forecasts, to bat fatalities predictions, to bat demography. In the remaining hour, we facilitate an interactive activity to explore how the approach could be implemented in other countries or offshore. Groups will discuss how the framework, or a similar approach, can be applied in their country, what the approach might look like in emerging markets, where data may be limited, and how useful the approach is. Results. Participants will leave the

workshop with an understanding of the framework and how they could implement an approach in their country or region of interest. Conclusion. The workshop will end with a summary of the interactive session that highlights scientific and methodological gaps, how we can consider issues associated with future deployment in emerging markets, and other issues related to large-scale wind energy deployment and integrative science.

Key words: bat fatalities, development limits, energy modelling, population demography, trade offs

WHERE DO YOU START? CONCEPTIONAL FRAMING OF COMPENSATORY MITIGATION FOR ONSHORE AND OFFSHORE WIND FARMS

Atma Khalsa[1], Scott Johnston[2], Laura Nagy[3], Kate Williams[4]
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Many wind projects, both onshore and offshore, require compensatory mitigation. Although mitigation for some species is clearly defined, creative mitigation solutions are increasingly required as renewables expand into new regions where there is no precedent for compensatory mitigation and/or new species may be affected by large-scale development, including species that are legally protected or of substantial conservation concern. In this panel, we will introduce a conceptual framework that developers and regulators must navigate to identify and enact compensatory mitigation efforts, from high level determination of focal species/habitats for mitigation and opportunity identification (i.e., actions to increase survival or conserve habitat) to a narrower list of feasible options for mitigation actions, to creating the supporting logic and metrics to determine the appropriate mitigation levels and measure outcomes. Following this introduction, panelists will highlight: 1) examples of where cooperation between the permitting agency and developer allowed creative solutions to move forward, 2) how sharing of information among cooperating partners and experts can provide substantive insight and lead to better outcomes, 3) where well-intentioned regulatory language can result in conflicts between regulatory requirements and biologically meaningful solutions, and 4) similarities and differences in how the conceptual framework for compensatory mitigation may also apply to net positive impact goals. We will then provide examples for species impacted both onshore and offshore, and focus on substantial time for discussion among panelists, including perspectives from regulatory agencies, developers, and other stakeholders.
Panelists will include Peter Robson (Scottish Power), Kari Soltau (Burns & McDonnell), Samir Whitaker (Orsted), Atma Khalsa (Avangrid), and Scott Johnston (U.S. Fish and Wildlife Service).

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PANELS

NATURE POSITIVE WIND ENERGY? AN OVERVIEW OF THE CHALLENGES AND OPPORTUNITIES

Samir Whitaker *(Orsted)*, **David Wilson** *(The Biodiversity Consultancy)*,
Jay Diffendorfer *(U.S. Geological Survey)*, **Lori Anna Conzo** *(International Finance Corporation)*,
Luc Hoogenstein *(ENECO)*, **Peter Robson** *(Scottish Power)*
Moderator: **Ed Arnett,** *The Wildlife Society*

The scale and pace of wind energy developments required to meet global climate targets is unprecedented. The global climate and biodiversity crises are interlinked, and it is vital that this expansion of new energy must adhere to the mitigation hierarchy to ensure there is no net loss of biodiversity, and there are increasing regulatory requirements and voluntary commitments (and a clear need) to go beyond and ensure net positive and nature positive outcomes for biodiversity. This session will aim to provide the audience with perspectives on how developers, financial institutions, researchers and consultants understand and approach the concepts of "nature positive" and how "net positive impact" fits within it with focus, case studies and lessons from wind energy projects and associated infrastructure.
This panel discussion features the following two abstracts:

NET POSITIVE IMPACT FOR BIODIVERSITY AND OFFSHORE WIND – CHALLENGES AND CONSIDERATIONS

Claire Fletcher[1], David Wilson[1], *[1]The Biodiversity Consultancy, CB2 1SJ, Cambridge, UK*
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Offshore wind is critical to the energy transition and the pace of development is accelerating. It is crucial this does not happen at the expense of nature, and there are increasingly ambitions for wind projects to have a Net Positive Impact (NPI) on biodiversity. While this sounds a simple concept (and, importantly, different from the emerging 'nature positive' concept), it conceals a significant amount of complexity and challenges – some specific to offshore wind and some common to biodiversity management and mitigation in general. This presentation will outline key steps and actions, and explore some of the challenges, needed to demonstrate project-level NPI for biodiversity. 1. Define what features will be tracked. NPI for every single biodiversity feature is not likely to be practical or feasible, so projects will need to complete some form of prioritisation to define the features of importance. How does a project identify priority features: conservation status, stakeholder importance, sensitivity to impacts? Then, does an NPI objective apply to all features, or a subset (e.g., those with significant residual impacts). 2. Set a metric and sampling or monitoring approach for each feature. This is likely to be different for each feature, although proxies could be useful for some groups of similar species. Area, or area*quality, and number of individuals are commonly used metrics, but what about more challenging situations like when projects may impact migration routes? 3. Establish baseline conditions: this may require targeted surveys or existing datasets depending on the feature. These conditions need to be established for both the negatively-impacted population and where positive actions (i.e., offsets) are likely to be implemented – noting these may be in very different areas. 4. Be transparent about how to deal with 'impossibilities and uncertainties' – features for which impacts or gains cannot be meaningfully quantified, which have large uncertainties, or for which gains are not feasible. How should these cases be addressed and incorporated into an NPI commitment? 5. Define a process for aggregating and reporting on results, both to determine when project-level NPI has been achieved, and, where relevant, aggregating project results from across a portfolio to determine when corporate-level NPI has been achieved. Does project-level NPI mean NPI for all features or for a majority? Is impact significance or sensitivity a factor, and should any weightings be applied? Being clear on what can be claimed, and when, is essential for credibility, reporting and disclosure.

Key words: Planning, mitigation, NPI

BIODIVERSITY METRIC: TOWARDS A NET POSITIVE EFFECT ON BIODIVERSITY

Luc Hoogenstein[1], *[1]Eneco, 3000 BA, Rotterdam, The Netherlands*
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Eneco's ambition on biodiversity is that all its investment decisions on new renewables assets should have a net positive effect on biodiversity from 2025 onwards. Eneco wants to apply this for the construction and operational phase, for both on- and offshore renewable energy assets. Arcadis has developed an approach for Eneco to restore nature and become net biodiversity positive for each new project. This approach is on top of business as usual, which already minimizes the negative impact on biodiversity. The Biodiversity Metric 3.1, a tool in use with the United Kingdom authorities, was found most suitable to support Eneco's purposes. In 2023 6 pilot projects have started to test the Biodiversity Metric on new sustainable energy projects, including the proposed wind farm at Houffalize, Belgium. During our presentation we will give insight on the following subjects based on our experiences in Houffalize: • Biodiversity impact of new Eneco's wind farms • The Biodiversity Metric explained • First results Within scope of the Biodiversity Metric are: • Direct local impacts on biodiversity at the site of specific planned assets. • Impact drivers limited to land use change (including fragmentation, collision risk, etc.) as this is by far the main pressure at site level. • Construction phase (of access roads, platforms, and the transport of material) and operation phase (including maintenance and anything to make the energy asset run properly). In parallel to the usual practice to be compliant with the relevant legislation (EIA, permits), Eneco applies the Biodiversity Metric 3.1 to calculate both the negative impact an asset may have (pre biodiversity units) and the required volume of nature recovery to achieve biodiversity positive. Nature recovery measures can be applied within the project site, near the project site (locally) and/or further away, as far as the combined restoration measures are sufficient for achieving biodiversity positive.
Key words: Biodiversity, method, net positive effect

THE ROLE OF IFIs IN REDUCING BIODIVERSITY RISKS AND IMPACTS AT RENEWABLE ENERGY PROJECTS, CASE STUDIES

Carla Maria Ariñez Sanjines[1], Alexandra Lima Lopes Martins de Freitas[1], Lori Anna Conzo[2], Beatrice Yulo Gomez[3], Robert Adamczyk[4]

[1]FMO, [2]International Finance Corporation, [3]Asian Development Bank, [4]European Bank for Reconstruction and Development

Moderator: Tris Allinson, BridLife International

Development Finance Institutions (DFIs) are key facilitators in the deployment of renewable energy globally. Such institutions not only provide financing for such developments but also require projects to comply with environmental and social safeguards which often surpass national regulatory standards. In this panel, representatives from national and multilateral DFIs will discuss biodiversity aspects of these safeguards in the context of wind energy projects in the Balkan Region, as well as emerging renewable energy markets.

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SPECIAL SESSIONS

HOW TO DO BUILT AN ECOLOGICALLY FRIENDLY WINDFARM?

Marin van Regteren[1,2], Hermione van Zutphen[2], Jeroen Kwakkel[3], Lisa Hoekema[3]

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Proposal for a special session with oral presentations under topic 5 or 7, with multiple presenters on different subtopics of the Windfarm Ecowende. Proposed subtopics are 1) generic introduction; 2) birds and bats; 3) marine mammals and 4) nature enhancement for fish, benthos and habitats. Details of separate topics did notfit the maximum word count. If preferable, we can submit these abstracts separately. In December 2022, the Dutch government awarded the permit to develop Hollandse Kust West (HKW) site VI to Ecowende. Ecowende will build the first offshore wind farm with a focus on ecology – from design, construction and operation to research and knowledge sharing. We do this by minimizing the negative effects on the ecosystem as much as possible while stimulating positive effects. As such, we find ourselves at the start of the mission to develop future wind farms with a net positive impact and we are working together with various ecological experts, organizations and institutions to stimulate a flourishing ecosystem: minimize impact on marine mammals, birds and bats, and promote a vibrant marine life. We will provide insight in our vision for HKW site VI and how this vision is integrated into the design, construction, installation and operations of the wind farm. To make the most positive contribution possible, our approach meets five requirements: • Holistic, because everything is connected within the North sea ecosystem; • Customized, because the effects of our measures will differ per species (group); • The full project lifecycle, because every phase will have a different impact on the ecology; • Continuous improvement, throught the evaluation of new insights; • Filling knowledge gaps, so that future wind farms will have more knowledge regarding the ecology of the North Sea and the effectiveness of our measures.

Key words: Offshore wind, ecological research, mitigation measures, nature enhancement, knowledge sharing

GRAND CHALLENGES IN WIND ENERGY RESEARCH – UPDATES FROM TEM #109

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In early 2023, the International Energy Agency Wind Technology Collaboration Programme (IEA Wind) convened a Topical Expert Meeting (TEM #109) on the Grand Challenges in the Science of Wind Energy. This meeting brought together approximately 100 experts from around the world to discuss how to design wind turbines and wind plants for wind energy to supply up to 50% of future electricity demand in a carbon-neutral energy system. To do this, experts from the following five research areas – atmosphere, turbine, plant and grid, environment, and social – met in their own groups and in breakout sessions with members of other groups to identify knowledge gaps and opportunities to advance research. Considerable time was spent identifying links between the five traditionally separate scientific areas, identifying cross disciplinary issues, and proposing initiatives to create a more holistic approach to the design and deployment of wind energy facilities. In this presentation we will 1) share information with CWW attendees about the aforementioned meeting; 2) summarize the critical issues for environmental co-design, initiatives, and need for holistic design; and 3) provide multiple perspectives on how we collaborate to advance these efforts. If this abstract is selected as part of a panel discussion at the CWW, the objectives would be the same as above. Although the final panelists have not been identified, the panel will include a moderator and someone to provide an overview of critical issues identified at the TEM #109. It will also include three to five individuals who can speak to these issues with expertise in wind turbine engineering, technology integration, wind plant operations, and regulatory frameworks. We have been in contact with several of our colleagues who participated in TEM #109 and they will be attending the upcoming CWW. We are confident that we will be successful in recruiting excellent speakers who collectively will represent a range of countries and have varied expertise and perspectives.
Key words: Environmental co-design, environmental costs and benefits, future impacts and tradeoffs, holistic design

REDUCING UNCERTAINTY AND ASSESSING BAT POPULATIONS IN DOMINICAN REPUBLIC

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In this session, three of the collaborating scientists will present an overview of a recently completed acoustic bat inventory of the Dominican Republic, a project whose primary objective was to gain new insights into the national population sizes of three species of bats that are from collision-susceptible taxa, and that have elevated conservation status, but whose distribution and abundance on Hispaniola were previously virtually unknown, due to a historical lack of acoustic bat surveys on the Island. Caleb Gordon, the project director, will present an overview of the project's background, purpose, and the significance of the results in the context of wind-wildlife science. Rosa Palmer, the project's lead mammalogist, will describe the project's primary field and acoustic analysis methodology, as well as a biological perspective on the study's principal findings. Paul Rabie, the project's lead statistician, will describe the statistical modeling approach used to make inferences about bat population sizes derived from bat acoustic activity data, with an emphasis on future research that is needed in order to realize the full potential of this modeling technique as a tool for understanding the population sizes of bats of interest to wind-wildlife scientists.

THE EMERGING COLLISION RISKS TO OLD WORLD FRUIT BATS

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Fruit bats are predominantly found in tropical and subtropical regions in Africa, Asia, Australia and parts of the Pacific Islands. They occupy a pivotal ecological niche as both pollinators and seed dispersers contributing significantly to the health and stability of the ecosystems they inhabit. Fruit bats face many challenges including habitat loss, hunting, conflict with farmers, heat stress and climate change. With the expansion of wind energy into these regions, collision with turbines is an emerging issue and creates a unique set of challenges for sustainable energy generation and the conservation of these Old World fruit bats.

This special session features the following three abstracts:

HOW CAN AUSTRALIA LEAD THE EMERGING ISSUE AROUND FRUIT BAT COLLISIONS?

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Australia is lagging behind in its response to mitigating and reducing bat collisions at wind farms. This may in part be due to the poor image of bats and the misconception that bats are large, noisy and invasive in our cities and towns as when Australians think of bats, they think of our flying foxes. All of our microbats are data deficient, but our flying foxes are easy to see and much easier to study. Large old world fruit bats (LOWFB) include flying foxes are subject to many pressures including habitat loss, human wildlife conflict, hunting for food and heat stress which has led to over 70% of the global LOWFBs being listed as vulnerable or worse. Australia is similar, of the 6 species we are custodians of, 1 flying fox is critically endangered, another due to be up-listed from endangered to critically endangered and another listed as vulnerable. LOWFBs are keystone species and their loss will have cascading affects for pollination and seed dispersal across their regions. Australia is now beginning to record wind farm impacts to flying foxes and it is likely that across the entire global range of LOWFBs collisions with turbines is adding another pressure. There is limited global knowledge and sharing in this space with few operators prepared to release information and many of the countries where this conflict could occur absent from meetings like CWW. With limited information from south east Asia and Oceania being presented in global forums, how we collectively respond to this emerging issue is a question the industry needs to consider if it is to continue to develop sustainably, particularly in regions with low socio economics and a poor history of protection for LOWFBs. Despite a poor response to microbats, Australia could be an ideal place to provide research leadership on this issue. What is needed is strong collaborations, sharing of knowledge and a willingness to work together to create these better outcomes.
Key words: Fruitbat, collaboration, policy, knowledge sharing

GREY-HEADED FLYING-FOX MOVEMENTS – AN EMERGING ISSUE FOR WIND ENERGY DEVELOPMENT IN AUSTRALIA

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South western Victoria has seen a rise in wind energy developments over the past two decades. Understanding Grey-headed Flying-fox movements in response to changes in resource suitability and availability is important to assess potential impact of wind energy on such mobile species. The Grey-headed Flying-fox distribution extends from north-eastern to south-eastern Australia and over recent decades the population has been expanding further south. The species has now formed a number of seasonal and permanent camps in Victoria and South Australia. The species moves in response to seasonal food availability and part of the population migrates annually from southern latitudes to northern Australia in autumn, before the onset of the cooler winter months. Individuals also move shorter distances locally, flying out to feed from temporary camps, which also form in autumn. Recently, collisions of Grey-headed Flying-foxes have been recorded at wind farms in areas where the species had not been previously recorded or detected in pre-operational surveys. The dynamic nature of the species' movements and formation of seasonal camps has made it challenging to identify areas of risk for wind energy developments as it has not been possible to predict such movements or camp locations. Understanding how to assess the potential collision risk and implementing impact avoidance and mitigation has become an emerging issue for managing the potential impact of wind energy developments to the Grey-headed Flying-fox population.
Key words: Collision risk, local movements, mitigation and management

USING NEW WORLD TECHNOLOGY TO TRACK OLD WORLD FRUIT BATS - THERE IS NOT A ONE-SIZE-FITS-ALL APPROACH.

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A variety of Old World fruit bats (Pteropodidae) occur throughout the tropics and sub-tropics of the Africa, Asia, and the Pacific Islands. They are vital pollinators and seed dispersers, contributing to forest regeneration and pollination of economically important plants. Fruit bats face a myriad of known threats globally, such as habitat destruction, roost disturbance, conflict with fruit growers, epidemic disease, hunting and trade, tropical storms, and recently, wind energy. As a result, some species are facing serious population declines. Global numbers of fruit bat fatalities related to wind energy are unknown, due to limited publicly available literature from countries with fruit bats, however, fruit bat fatalities are known from South, East and West Africa. As wind energy development accelerates in emerging market countries in Africa and Asia-Pacific, the risk of wind turbine-related fruit bat fatalities will also increase, along with detrimental impacts on the ecosystem services these bats provide. Monitoring insectivorous bat activity using ultrasonic bat detectors to predict, minimize, or avoid bat fatality risk at wind energy facilities is common practice globally. However, the majority of fruit bats do not echolocate, and because they are nocturnal, they cannot be visually surveyed for risk during the day. Risk assessments for fruit bats require alternative monitoring methods to determine bat activity levels at wind energy facilities. This is particularly important in areas where large concentrations of fruit bats are expected at certain times of the year, (e.g., migrating African Straw-coloured Fruit Bat [Eidelon helvum]) in Zambia during late spring/ early summer. Understanding the strengths and limitations of various alternative technologies, tailoring the monitoring approach to the landscape, biology, and behavior of the fruit bats in that area, and having a clearly defined question with regards to the study are vital in determining appropriate technology, and how and when to use them. Such technologies can also be very expensive; choosing the correct solution for a particular study is important. We have designed and implemented numerous bat and avian surveys using a variety of technological solutions; such experience can be transferred for the purpose of monitoring fruit bat activity at wind energy facilities. We present examples of the various technologies available to monitor fruit bat activity (e.g., migration, roost sites, emergence, and foraging activity) and when and where it is appropriate to use each; these include radar, stationary thermal cameras, drones, night-vision goggles, and thermal binoculars.
Key words: Fruit bats, technology, wind energy, monitoring

To Content

12-MINUTE TALKS

SETTING OBJECTIVES FOR NATURE-INCLUSIVE OFFSHORE WIND FARM DEVELOPMENT

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Rapid changes in the marine environment are taking place, including the huge roll-out of offshore wind farms. These changes require structured policies with clearly defined objectives to find middle ground between nature values and wind farm development. Without proper objectives, the policies could go into all directions and interfere with each other. Setting policies for different systems involving different usages, would benefit from a generic approach to determine the objectives. Such an approach should include standards for creating objectives as well as for implementing targets to achieve them. In general, marine infrastructure is primarily designed to meet engineering and financial criteria, without considering its value as habitat. However, it modifies seascapes by replacing natural habitats and changing environmental conditions critical to habitat persistence. Marine infrastructure can be designed to incorporate ecological principles that benefit marine life. When setting the ecological objectives for infrastructural development in the marine environment, one can define objectives for limiting its negative impact, but even better, on can try to stimulate positive impact with the usage function. The successful development and implementation of a policy for nature-inclusive development of marine infrastructure, including offshore wind farms, requires the definition of clear strategic and operational objectives. These will support guidance to the developers in designing and constructing the infrastructure nature-friendly, and in setting up relevant monitoring programs to evaluate the measures taken. We present a systematic approach to identify the nature-inclusive design potential of new marine infrastructure. It is a stepwise procedure, assessing the local natural and anthropogenic system, making an inventory of potential nature friendly design solutions, and ranking measures systematically to support decision making. We demonstrate the approach by applying it to offshore windfarm development in the North Sea.
Key words: objective, policy, nature, offshore wind

FINDING SOLUTIONS FOR OFFSHORE WIND AND NATURE IN ENGLAND

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The ambitious British Energy Security Strategy aims to deliver 50GW of offshore wind by 2030. To achieve this, it sets out to consider the environment at a strategic level allowing speeding up development while improving the marine environment. Underpinning this, Natural England's 'Approach to Offshore Wind' describes a vision for thriving marine and coastal nature alongside low impact offshore wind energy, tackling both climate and biodiversity emergencies. Key case studies will be presented to demonstrate how the aims of this approach are being met. POSEIDON is a multi-year, multi-partner project establishing a robust evidence base to be made accessible through new mapping tools. These will support authorities, developers, and policy makers to make better informed decisions and minimise conflict by providing up-to-date, high-quality data that identifies the most appropriate sites for development and mitigation opportunities. Existing data about seabirds, marine mammals, and benthic habitats have been collated and assessed. New surveys are designed to address knowledge gaps through collecting new data, collaborating with other data collection projects, factoring in confidence in current models and priority areas for offshore wind development. Work has started on design of the mapping and modelling tools. Outputs will include updated spatial models for key receptors most vulnerable to offshore wind impact and an environmental risk and opportunity map to help guide future offshore wind development and feed into wider marine planning. Natural England has published 'Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards' . This project aims to facilitate the development of low impact offshore wind by increasing clarity for industry, regulators and other stakeholders over data and evidence requirements for key ecological receptors which pose a consenting risk for projects. This is done for each stage of offshore wind development, from pre-application through to post-consent. Integral to the project, the team undertook extensive engagement with a stakeholder focus group to obtain input, feedback and advice. The advice documents are considered 'live' and will be periodically updated to reflect evolving best practice in environmental assessments, new evidence, planning reforms and in response to Government policy and initiatives. As well as introducing the above significant projects, the presentation will provide up to date news on delivery of the fast-paced objectives of the British Energy Security Strategy.

Key words: offshore wind, wildlife, planning, mapping, advice

UPSCALING WINDENERGY: HOW TO PREDICT FUTURE CUMULATIVE IMPACTS OF OFFSHORE WINDFARMS IN THE NETHERLANDS?

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The Netherlands are working towards sustainable energy that is available to everyone. When implementing the plans for large-scale development of offshore wind energy, the government takes the different interests at sea into consideration. The planning starts with the designation of a windfarm zone, by designing preliminary sketches for the sites per wind farm zone, leading to the moment of actual construction and the successive operational phase. In all steps an assessment of the cumulative ecological effects, at North Sea scale, of offshore windfarms is made. So far, two strategies of assessing ecological impacts of different aspects of future offshore wind farm developments have been developed: VECI (the Exploration of ecological cumulative impact) and KEC (Framework Ecology and Cumulation). The VECI assesses in a qualitative manner the effects of longer-term wind scenarios. The KEC addresses quantitatively the shorter-term scenarios for which more exact information on both the intended development and the possible ecological effects can be compiled. Points addressed in both strategies are b.e. effects of collision and habitatloss on birds, effects of impulsive underwater sound during construction on marine mammals, collision risk of migrating bats and ccosystem effects. Both assessments use the same density maps with habitat suitability components, the same insights into effects and the same acceptable levels of impact, which determine the ecological thresholds. Both strategies are developed under the Wozep research program. The KEC and VECI approach mainly differ in the way the results should be interpreted. The VECI approach for the longer-term future scenarios is more qualitative, providing an estimated insight for future scenario's based on current knowledge that is more susceptible to change compared to the KEC approach, that is dealing with shorter-term plans and permits. By making an ecological assessment for every step of the regulatory and planning proces of windfarm projects, the cumulative ecological impact will be getting more clear. By using both VECI and KEC we can make the best possible estimation of the cumulative impact, so we are not faced with last minute insights some scenario's will have too much ecological impact. Because of the assessments the point of focus for research by the Wozep-programm, mitigation measures, allocation, etc. can be addressed in an early stage. By example, the KEC pointed out a threshold for pilingnoise was necessary. So in the permits this is implemented. In this way the two strategies will contribute to an environmentally responsible building of offshore windfarms.

Key words: Offshore, Cumulative impact, focus research/mitigation in time

INTEGRATING SPECIES CONSERVATION CONSIDERATIONS INTO STRATEGIC, REGIONAL WIND ENERGY PLANNING USING HABITAT MODELLING

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Wind power development is crucial for meeting climate targets, but finding suitable space for onshore wind power is increasingly challenging due to conflicts with competing land uses, including nature and species conservation. To address this issue, our project aimed to demonstrate the suitability of habitat modelling approaches for identifying core priority areas for the conservation of sensitive bird populations to support strategic regional wind energy planning in German states. We developed a model based on publicly available geodata on land-use (Copernicus satellite program) and bird monitoring data from German states, focusing on three relevant species: Milvus milvus, Milvus migrans, and Pandion haliaetus, which show different habitat preferences. The modelling was conducted using logistic regressions in R, achieving good evaluation results. Our lean model can predict species occurrence based on habitat parameters with high confidence, enabling us to identify core priority areas for the conservation of the three bird species populations in our study regions. Our presentation will discuss the strengths and limitations of the habitat modelling approach, including the need for high-quality data and the importance of incorporating uncertainty and variability into the modelling process. We will also discuss the potential of the identification of core priority areas for bird populations for promoting sustainable and environmentally responsible wind energy development and supporting the designation of go-to or no-go areas for wind energy, as required by recent EU regulations. The presentation will be of interest to wind energy developers, environmental planners, and policy makers involved in wind energy development and interested in the use of habitat modelling for species conservation and strategic wind energy planning. Our work demonstrates the potential of incorporating species conservation considerations into strategic planning for wind energy projects and offers a replicable and transparent approach for identifying core priority areas for species conservation in the context of wind energy development.

Key words: regional planning, wind energy sites, red kite, osprey, habitat suitability

THE NEED FOR REGIONAL COLLABORATION TO UNDERPIN ENVIRONMENTAL IMPACT ASSESSMENTS OF BIRDS FOR OFFSHORE WIND PROJECTS IN AUSTRALIA'S BASS STRAIT

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Offshore wind energy is in its infancy within Australia with enabling legislation, the Offshore Electricity Infrastructure Act 2021, taking effect in June 2022. Nevertheless, momentum is building and it is emerging as a significant potential contributor to Australia's overdue energy transition. The first applications for tenure, in the form of a Feasibility Licence, have been lodged in April 2023. These tenure applications are for projects off the Gippsland coastline in south-eastern Australia within the Bass Strait. Australia faces some unique challenges in environmental impact assessment as its' first offshore wind projects progress towards approval applications. These include a regulatory framework split between jurisdictions and the lack of marine spatial planning. Furthermore, a relative absence of baseline species information alongside an abundance of potentially impacted fauna species leaves Australia at a relative disadvantage in order to efficiently undertake comprehensive environmental impact assessments. There remains limited guidance on cumulative impact assessment methods and therefore a risk of different projects applying different methods and assumptions for the same species. All of these challenges are occurring in the context of a scarcity of the appropriate expertise, resources and equipment. Comparing to the state of knowledge of bird species in Europe's North Sea, this presentation will look at the still evolving environmental impact assessment requirements for birds for offshore wind projects in Australia's Bass Strait. The area is important for seabirds, shorebirds and terrestrial migrants. Intensive baseline surveys over 2-3 years are required. It is likely that some overlap and duplication of significant effort will occur across different projects. This also introduces the potential for excessive disturbance of sensitive populations from the surveys themselves. To tackle these complex issues, collaboration to better understand the presence of and risks to listed threatened species, requires cooperation from across the offshore wind sector, scientists, research institutions, advisers and regulators. Commencing a collaborative effort has increasing urgency and this presentation will consider regional cooperative models from other parts of the world and their potential for application within Australia.
Key words: birds, offshore, environmental, impact, assessment

THE ROLE OF STRATEGIC ENVIRONMENTAL ASSESSMENT (SEA) FOR TAKING PRECAUTIONARY DECISIONS AT REGIONAL LEVEL – CHALLENGES AND CHANCES FOR WIND ENERGY DEVELOPMENT

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A comprehensive transformation of the energy production and consumption is needed to meet climate targets. Particularly wind and solar energy deserve strategic planning in order to identify possible conflicting interests with competing sectors as well as health and/ or biodiversity targets and to minimize them as far as possible. In this context experts discuss the role of Strategic Environmental Assessment (SEA) in order to make trade-offs transparent and evident and prepare decision-making at regional level through an integrated look at environmental issues and their interrelationships. With the REPowerEU plan and the emergency measures adopted by the EU commission in 2022 which aim at streamlining development of renewable energy using “go-to” areas for renewable energy production and simplified permitting procedures relevance of SEA and regional decision making has further gained importance. However, several open questions remain, not alone suitability of species assessments in strategic regional level planning for wind power development. With studies pointing out the lack of data (or its accessibility) relevant for decisions about wind energy projects to be taken at the regional level. In our contribution we discuss the potential of SEAs as currently performed in practice as basis for project level decisions about wind energy projects using Austrian and German cases. In particular we evaluate the consideration of species concerns in SEAs and the data and information being used on strategic level. We will critically discuss the level of uncertainty related to data basis in SEAs. Finally, we will outline the likely potential of improved environmental data management and data access for strategic wind energy planning. Approaches such as comprehensive online data platforms, which provide up to date, harmonized, and usable digital environmental data can support the execution of impact assessments such as SEAs. Automated data capture and interrogation, integrated GIS and the use of interactive technologies are digital solutions and approaches that have been integrated recently into environmental planning and impact assessments (González Del Campo 2017, Bressane et al. 2020). Some studies discuss artificial intelligence (AI) approaches from the perspective of increasing efficiency in data analysis through machine learning methods for impact assessment practice (Ulibarri et al. 2019, Elia et al. 2020).
Key words: Strategic Environmental Assessment, Got-to areas, Regional planning, green-to-green conflict

BALANCING SOCIO-ECOLOGICAL & ECONOMY TRADE-OFFS IN SPATIAL PLANNING OF WIND-POWER PROJECTS

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Reconciled siting of onshore/offshore wind power - accounting for restriction areas, ecosystem services, wind resources, production potential (kWh), technical requirements and levelized costs of energy production (Euro/kWh) is a challenging exercise for developers, spatial planners, and decision makers. ConSite Wind (developed by NINA) is an open web-app designed to overcome these challenges, based on cloud-computing resources and a user interface customized for non-expert end users. A core component in ConSite Wind is the ecosystem approach which helps to highlight the socio-ecological values and multi-functionality of the landscape (in terms of diversified land use, complex landscape structures and competing stakeholder interests). Based on the stakeholder preference weights, a socio-ecological map is aggregated as a trade-off between the provisioning, regulating, cultural and supporting ecosystem service maps. The next step is to balance these socio-ecological landscape values with the landscapes production potential (in terms of kWh per year). The resulting trade-off map is then spatially filtered to account for compliance with relevant decision rules for siting of wind power plants (wind conditions, installed capacity requirements, production costs, turbine design, distance to grid-connection, technological and environmental requirements). As a part of this process "No-go zones" (areas with hard restrictions) are automatically excluded from further consideration. To prioritize and further facilitate the scoping process ConSite Wind helps to identify suitable development areas (high production potential/low socio-ecological values), areas requiring mitigation (medium to high production potential/low to medium socio-ecological values) and areas to avoid due to high conflict potential/kWh (low production potential/low to high socio-ecological values and low to high production potential/high socio-ecological values). The suitable areas and the areas requiring mitigation can finally be further evaluated according to wind farm layout and installed capacity requirements (type and number of a given turbine design) to segment the most suitable development areas based on patch size and shape. The diversity of interests in wind power development projects is high, and it is most often very difficult to obtain full consensus about a final decision. The purpose of ConSite Wind web-app is not necessarily to reach unanimity, but to predict and visualise spatial consequences of different decision scenarios and thus enable developers, consenting/environmental authorities, and the public to take more informed, transparent, and re-examinable decisions in future wind power development projects. This, we hope to demonstrate in our presentation of the web-app at CWW 2023.

Key words: Spatial MCDA, Ecosystem services, socio-ecological-economical trade-offs

SHARING THE SPACE? - A MULTI-CRITERIA SCENARIO FRAMEWORK TO MODEL THE ENERGY-BIODIVERSITY-LAND NEXUS FOR REGIONAL RENEWABLE ENERGY PLANNING

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Balancing renewable energy supply and biodiversity conservation has become increasingly vital amid the climate, energy, and biodiversity crises. It often triggers trade-offs such as competition for land use and potential impacts on species and habitats. In Germany, state- and regional-specific spatial targets for wind energy are now to be achieved through a positive planning approach. To enhance bird and bat species protection early on, relevant spatial designations are discussed for the regional planning level, known as ‘priority zones’ for species. These are areas with a high degree of habitat suitability and significant breeding relevance. However, species priority zones also raise the question of whether the limited areas suitable for wind energy are further reduced, and whether the state- and regional-specific spatial targets of around 2% of sites for wind energy can still be achieved. To support decision makers, a multi-criteria scenario framework has been developed and analyzed. This invokes a habitat model of priority zones for species conservation and uses techniques from the intuitive logics scenario planning method. Based on a regional case study, scenarios were developed to elaborate how planning criteria that may compete with wind energy still can go hand in hand to achieve the energy targets (e.g., priority zones for species protection, settlement buffers, forests, as well as ground-mounted solar energy in the energy mix, and others). The results suggest that, compared to other planning criteria, the species priority zones had limited competition with the spatial wind energy targets. The spatial target can be achieved with only minimal adjustments, such as allowing wind energy in 1-3% of so far completely protected landscapes with a recreational focus. Alternatively, sufficient space would exist to allow part of the wind energy spatial targets to be replaced by ground-mounted solar energy, while also still achieving the necessary solar development targets. More flexible planning approaches can obviously help resolve the otherwise conflict between wind energy and species protection. It is shown that the framework allows for the quantification of ‘costs’ and ‘benefits’ in wind energy planning. It provides transparent assessments of trade-offs in terms of multiple objectives. How far these benefits can be achieved within the confines of preoccupied and siloed organizations is an ongoing research topic.
Key words: Wind (and PV) renewable energy planning, species priority zones, multi-objective optimization, trade-offs, spatial energy targets

VALUE AGGREGATION IN ENVIRONMENTAL PERMIT ASSESSMENTS FOR WIND ENERGY FACILITIES, -AN EXAMPLE FROM SWEDEN

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Transparency and predictability are requirements that are often mentioned in the public discussion in the context of wind power establishment. Decision support tools based on theoretically sound reasoning models can facilitate meeting these requirements. To lay the groundwork for a decision-making tool it is important to know how the decision-making process proceeds and what kind of problems decision-makers face during the process. Furthermore, factors regulating the decision-making need to be considered. The work presented here focused on a decision-making model that could be useful in the context of wind power establishment, and specifically for permit officers when they evaluate permit applications. Assessment of an environmental application for wind power establishment is a multi-criteria problem including the core problem: whether to grant permission or not. In Sweden, County Administrative Boards decide the outcomes of these kinds of applications. In this study, five permit officers were interviewed and their difficulties regarding necessary assessments and trade-offs was investigated. From an MCDA point of view, we investigated if permit officers use condition-based aggregation, value difference-based aggregation or a combination of both when evaluating permit applications. When the permit officers interviewed in this study evaluate an application with its EIA, in most cases they inspect each aspect separately to assess if it is on an acceptable level for a wind power establishment or not, i.e., they do not combine aspects and add up pros and cons. The commonly used type of aggregation was condition-based aggregation. Aggregation based on value differences, which means weighing together aspects for and against the wind power establishment, was considered difficult to apply by the respondents. Most of them agreed that some of the aspects that speak against granting permission could be aggregated but that aggregation of all aspects would be hard due to differences between aspects. In addition, the value of the main aspect that speaks for permission, climate friendly energy supply, is very difficult to estimate. Our findings indicate that aggregation based on value differences is difficult to handle. In the presentation, we will discuss how it could be done. If policymakers wish to make it possible to take both positive and negative aspects into consideration and to discuss the trade-offs transparently, the investigated method can be a way forward. Based on the article: Multi-criteria reasoning models for value aggregation in wind power permit application assessment Authors: Ulla Ahonen-Jonnarth, Åsa Elmqvist, Magnus Hjelmblom https://doi.org/10.1016/j.ref.2023.04.006

Key words: MCDA, trade-offs, permitting processes

ASSESSING ENVIRONMENTAL AND SPATIAL FACTORS FOR OFFSHORE RENEWABLE ENERGY DEVELOPMENT IN CROATIA

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With the growing adoption of wind as a renewable energy source in Croatia and the development of onshore wind farms, the exploration of offshore wind farms and other offshore renewable energy sources has become essential for achieving national and EU-level energy independence and climate neutrality by 2050. This is accelerated by the political climate in Europe and the REPowerEU Plan, the European Commission's plan which emphasizes rapidly deploying solar and wind energy projects and expediting permitting for renewables in low-risk renewable acceleration areas with the goal of rapid diversification of energy sources. An important step in this direction for Croatia was taken through the Action Plan for the uptake of Offshore Renewable Energy Sources. The key aspects of the study presented here include the environmental impacts of offshore renewable energy sources (ORES) and the identification of maritime areas for offshore renewables in Croatia, with a focus on wind power. The study examines the effects of ORES on marine benthic habitats, protected marine areas, NATURA 2000 sites, fish, marine mammals and turtles of the Adriatic Sea, bird breeding grounds and migratory routes. Additionally, the study analyzes the impacts of ORES on the landscape and seascape, considering the numerous coastal protected areas in Croatia and the significant contribution of tourism to the economy, and explores the possibilities for co-existence with other sectors. The research included a spatial analysis of potential development areas for ORES in the Adriatic Sea under Croatian jurisdiction, taking into account environmental impacts, technological limitations, and existing spatial constraints due to oil & gas exploitation concession fields and commercial marine traffic areas. As the first high-level, comprehensive approach to ORES in Croatia, this study provides valuable insights and a crucial starting point for further detailed studies, spatial planning, and the identification of "renewable acceleration" areas for ORES in the country.
Key words: Offshore renewable energy sources, environmental impact, offshore wind farms, spatial analysis

MIGRATION OF BATS AND OFFSHORE WINDFARM DEVELOPMENT IN DENMARK

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The development of offshore wind in Denmark and the surrounding countries include a large number of planned parks in the Baltic Sea and Kattegat. Denmark is also situated on the main corridor of the bat migrating from Fennoscandia to western Europe for the winter. Since 2020 more than 150 bat detectors have been installed for long-term monitoring of the bat activity on more than 100 locations along the coast of Norway, Sweden, Germany and Denmark and on buoys and on existing wind turbines in the Baltic Sea and Kattegat. Preliminary analyses show presence of bats even far from the coast, verifying that bats migrate across the sea. Data also suggest movement of resident bat populations to forage at sea especially in late summer. Several species are observed. However, a large majority of all observation are three species: Nathusius' Pipistrel, Common Noctule and Parti-coloured Bat. Observations on the sea are most frequent during autumn at night with low wind speed and weak tail wind. The time of the season and weather history of previous days are important factor in the prediction of bat migration. Attraction by the wind turbines is addressed through a study using similar bat detectors on the base of the wind turbine and on buoys around the wind turbines. Development of offshore windfarms should include survey of bats in areas in the Baltic Sea and in the southern part of the Kattegat Sea where bat migration is most likely. Post construction survey and adjustment of cut-in speed in certain time periods can be necessary in areas with potential risk for significant bat migration.

Key words: Bat migration, offshore wind farms, Environmental Impact Assessment, Nathusius' Pipistrel, Common Noctule

ASSESSING AVIAN COLLISION RISK AND SUSCEPTIBILITY IN BRAZILIAN WIND FARMS: A COMPARATIVE STUDY WITH GLOBAL TRENDS

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The effects and impacts of wind farms (WF) on birds have been widely studied in recent decades. However, the development and expansion of WFs have increased in recent years, occupying regions of the globe where this type of project did not previously exist and where there is significant avian diversity. In our study, we compiled information on bird species that occur in WFs and data on fatalities reported for some of these areas. The WFs are located in four Brazilian states: Rio Grande do Norte, Paraíba, Bahia, and Rio Grande do Sul. The species present in the WFs and those for which fatalities were recorded were grouped according to the bird orders they belong to. For fatalities, we used existing data from fatality monitoring programmes and harmonised them to assess collision values for bird orders, in accordance with Thaxter et al.'s study (2017). This enabled us to evaluate and compare whether global trends in susceptibility and collision risk are maintained in Brazil. In the studies analysed, a total of 244 species were identified across the 5 locations. Fatality data were collected over 2 to 3 years, totalling 6,202 individual searches of wind turbines. Fatalities were recorded for 12 species (belonging to 8 Orders), all with low conservation concern status, non-migratory, and with a broad geographical distribution in Brazil. The total observed mortality per turbine per year was 0.07 (+- 0.1) birds. The orders with the highest number of recorded individuals were Cathartiformes, Falconiformes, and Accipitriformes. The affected species were not the most abundant, indicating a weak relationship between bird abundance onsite and collision risk (which was expected). Important to highlight that one of the most affected orders (Cathartiformes) is due to the high number of fatalities recorded for american black vulture (Coragyps atratus), which are quite common throughout Brazil. Although not a specie with a threatened conservation status, special attention should begin to be given to this specie due to the significant development of new projects throughout Brazil. The results highlight that despite the great bird diversity in Brazil, only a small fraction of species was found to be affected by direct mortalities due to collision. At the order level, the results indicate that the affected groups were similar to those on a global scale. Thaxter's collision index can be used as an initial measure of species affected; however, other factors must be considered in the prediction of bird fatalities.
Key words: Collision, avian, susceptibility, Wind, Brazil

SEABIRD SENSITIVITY TO OFFSHORE WIND FARMS: AN INDIVIDUAL-BASED MODELLING APPROACH

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Offshore wind development is a key part of the strategy many countries are proposing to achieve net zero. However, such development can have negative impacts on protected species, such as seabirds, through collision or displacement. Collisions have a lethal effect, while displacement has energetic consequences with sub-lethal effects, potentially impacting future breeding success and/or survival. The non-breeding season is an under-studied period of the year with regards to offshore wind farm impacts on seabirds. However, improvements in tracking technology have enabled us to increase our understanding of this important part of the annual cycle. Our goal was to develop an individual-based model to predict the impacts of a floating offshore wind farm in the northern North Sea during the non-breeding season on two Norwegian populations of two seabird species: common guillemots Uria aalge breeding at Sklinna and black-legged kittiwakes Rissa tridactyla breeding in Ålesund. We used long-term tracking data obtained from geolocation-immersion loggers, collected as part of the SEATRACK project, to calculate distribution and activity budgets for each population throughout the non-breeding season. We ran simulations to estimate the overlap of each population with the wind farm development area. We calculated the risk of collision in kittiwakes using the stochastic Collision Risk Model and risk of displacement in guillemots using values from Peschko et al. (2020). We quantified the sub-lethal effects of displacement on guillemots by assuming an additional 30 minutes of flight to their activity budget and adjusted their energy expenditure accordingly. As the energetic impacts of displacement on guillemots are poorly understood, and may include reduced access to food, reduced foraging time, and increased escape behaviours, this additional flight time represented an energetic cost of displacement. Preliminary results indicated that 23% of kittiwakes overlapped with the development area for at least one day of the non-breeding season, but that kittiwakes had a very low risk of collision. We estimated 0.05% of the guillemot population was displaced, which had a negligible effect on total non-breeding season energy expenditure. Based on our results, this development is likely to result in minimal impact on these populations during the non-breeding season. However, the impact of this development when considered alongside other threats already occurring in the area (and any breeding season impacts) are unknown; thus, we aim next to expand our model to quantify the cumulative effects of this development and other threats on seabird populations breeding in the North-East Atlantic.

Key words: offshore wind, seabirds, individual-based modelling

FIRST GRIFFON VULTURES FATALITY MONITORING PROGRAM IN CROATIA

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Croatia holds a Griffon vulture Gyps fulvus population of around 100 pairs which have been the result of a long-term conservation effort. The population breeds in the Kvarner archipelago on the northern part of the Adriatic Sea and represents an important stronghold for the long-term preservation of the species in Europe. Nationally the population is considered endangered (EN), recently being removed from critically endangered due to the stabilisation in its population size. Nonetheless, several national and international projects strive to increase its conservation status. On the other hand, the boom in wind energy development introduced a new risk to the national population and could potentially jeopardise other conservation efforts. As a result of intensive wind energy development in recent years one of the largest wind farms in the region (39 turbines) was built in the proximity (less than 20 km) from the Vulture's colony in the mainland. The collision risk model predicted 1 vulture/year suggested that the fatalities could exceed national acceptable thresholds. Based on the suggestion from the baseline study additional management with the aim of mitigating the potential impacts at the site would be required. To monitor the fatalities and to assess the effectiveness of future mitigation measures a robust post-construction fatality monitoring program (PCFM) tailored around the habitat and Griffon Vulture characteristics at the site has to take place. The habitat at the site is a mixture of open land used for cattle grazing and beech forest with all three large European carnivores recorded (Brown Bear, Wolf, and Eurasian Lynx). This is the first PCFM program for Griffon Vultures in Croatia and represents a case study on how to design and conduct the fatality monitoring program for the species in the region. The griffon vulture is one of the most affected raptor by the wind energy, especially in Spain with an average fatality rate of 0.13 birds/turbine and year (range 0.04-0.54). We compare the existing PCFM protocols and associated biases (searcher efficiency and carcass removal) in the fatality estimation, and the effect of temporal variations in vulture fatalities related to food availability and livestock management, an aspect not included in the CRM models.

Key words: Gyps fulvus, PCFM, endangered species, carcass persistence, searcher efficiency

NUMBER OF BIRD COLLISIONS WITH ONSHORE WIND TURBINES IN JAPAN AND DEVELOPMENT OF SPECIES SENSITIVITY INDEX

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As of the end of June 2022, 2,605 onshore wind turbines (Total output 4,691MW) have been installed in Japan. As the number of installations increases, so too does the risk of bird mortality as a result of collisions with turbines. We created species sensitivity scores for 157 land birds in Hokkaido, Japan, where there are many installed wind turbines, to understand which species are most vulnerable to collision mortality and other impacts associated with wind turbines. The results showed that, with the exception of the Yellow-breasted Bunting Emberiza aureola, the species with the highest scores were Accipitriformes or other large species, including: White-tailed eagle Hariaeetus albicilla, Steller's sea eagle H. pelagicus, Oriental white stork Ciconia boyciana, Eastern marsh harrier Circus spilonotus, Red-crowned crane Grus japonensis, Mountain hawk-eagle Nisaetus nipalensis, Bean goose Anser fabalis, Peregrine falcon Falco peregrinus and Greater white-fronted goose A. albifrons. To test our sensitivity index, we compiled information on the number of carcasses detected around wind turbines in Japan. Drawing from a review of post-construction EIA reports, and personal observation from members of the WBSJ, we identified 604 bird collisions of 87 species up to January 2023, of which about 25% were reported following incidental observations by WBSJ members and 75% were reported in post-construction reports. These included: 94 Black kites Milvus migrans, 73 White-tailed eagles, 22 Black-tailed gull Larus ichthyaetus, 21 Common buzzard Buteo buteo, 18 Oriental turtle dove Streptopelia orientalis, 16 Slaty-backed gulls L. schistisagus, 15 Jungle crow Corvus macrorhynchos, 12 Eastern spot-billed duck Anas zonorhyncha, 10 Rhinoceros auklet Cerorhinca monocerata, 9 Common pheasant Phasianus colchicus, 9 Western osprey Pandion hariaetus, 8 Narcissus flycatcher Ficedula narcissina, 7 Japanese bush warbler Cettia diphone and 7 Meadow bunting E. cioides etc. There were spatial and seasonal patterns in carcass detections, with seabirds restricted to coastal sites and a peak in Passeriformes carcasses during the autumn migration season. In common with Atienza et al. (2014) and Thaxter et al. (2017), and as predicted by our sensitivity index, we found a high rate of collisions involving Accipitriformes, Charadriiformes and Passeriformes. However, we also detected high collision rates for Anseriformes, Galliformes and Columbiformes species which previous studies have suggested may be at relatively lower risk of collision. Previous analyses have been dominated by data collected from Europe and North America. Our results highlight the importance of considering data from other regions when making global assessments of species vulnerability to collision.
Key words: Collision death, Species sensitivity index, Japan, Onshore wind turbines, Regional difference

SYNTHETIC ANALYSIS OF POST-CONSTRUCTION DISPLACEMENT OF MARINE BIRDS FROM WIND ENERGY AREAS

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Displacement of marine birds from at-sea foraging, resting, and migratory habitat is frequently observed following construction of offshore wind energy installations. However, effects have varied widely among monitoring methods, locations, and species. The drivers of this variation are unclear but likely include a combination of study design parameters, differences in the magnitude of responses among species and seasons, and differences in wind farm locations and layouts. An understanding of the underlying factors driving both occurrence and detection of displacement effects is required to inform wind farm design and develop best practices for monitoring. We conducted a synthetic meta-analysis of existing literature to assess the state of knowledge on displacement effects. Drawing from 37 studies and reports on displacement of marine birds by wind energy infrastructure, we extracted the likelihood of detecting a change in distribution compared to pre-construction and/or reference sites, as well as the percent change in use of the wind energy area. We then modeled these outcomes as functions of wind farm characteristics (e.g., turbine density, latitude, distance from shore), bird characteristics (e.g., species, taxon, age, season), and the observation process (e.g., monitoring method, control area size and distance, years post-construction). We found that displacement effects varied among species, with the strongest effects observed during the breeding season. Effect detection increased with overall study area footprint and diminished with increasing distance from wind turbines. Wind farm characteristics were highly correlated with one another, but we observed stronger displacement effects at high-latitude, nearshore sites. Density of turbines within the wind farm footprint did not appear to affect displacement levels. More broadly, we found that extracting standardizing responses for meta-analysis was challenging due to differences in reporting among studies. We recommend that future monitoring studies clearly report both means and standard errors of underlying metrics (i.e., abundance and/or density) within clearly defined study areas to allow for robust comparison among sites, species, and survey methodologies.

Key words: displacement, marine birds, meta-analysis, offshore wind

REVIEW OF EVIDENCE TO SUPPORT GANNET (MORUS BASSANUS) DISPLACEMENT FROM OFFSHORE WIND FARMS.

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APEM undertook an evidence-based review and meta-analysis of gannet (Morus bassanus), to determine displacement rates for use in Environmental Impact Assessment (EIA) reporting. Evidence was collated from multiple sources, including 25 offshore wind farm (OWF) technical monitoring reports, published research papers and grey literature study reports that provide data on displacement effects associated with gannet. Avoidance behaviours observed by birds to OWFs are reported to have various impacts, which include displacement effects from the OWF footprint and surrounding area, avoidance effects to wind turbine generators (WTGs) (macro-, meso- and micro-) and barrier effects. This review focussed on displacement effect and macro-avoidance, which refers to avoidance to the presence of an OWF and not individual WTGs resulting in re-distribution of birds inside and outside of the OWF. The review collated and critically appraised studies from 25 OWFs encompassing 34 years of combined data from 30 reports and publications. Gannet displacement effects varied from no evidence of avoidance to strong avoidance, however, reported effects would either show; a) inferred macro-avoidance or a displacement rate of 60% or higher or b) imply a lack of evidence for macro-avoidance or displacement. The compilation of data and OWF design metrics provided the opportunity to determine which variables are associated with displacement effects seasonally. Fourteen variables were tested for differences in pairwise comparisons between OWFs grouped according to whether a high displacement effect (>75%) was shown or inferred and those suggested to have displacement effects of ≤75%. Four variables were shown to be significantly different between groups inferring an association with high displacement effect and avoidance behaviours, these variables were: density (WTGs/km2), OWF area, distance between WTGs and distance from shore. The review found a seasonal difference in displacement rates, significantly lower in the breeding season compared to the non-breeding season, across these data. Displacement rates for the breeding season ranged from 40-60% and from 60-75% during the non-breeding season. In summary, the review highlights that multiple factors may be associated with the magnitude of displacement effects from OWFs with similar attributes likely to demonstrate similar displacement effects dependent upon the season. Therefore, by considering OWF site attributes and the season when gannets reside within the study area the displacement rate can be refined from the broad range reported across all OWFs and tailored to an individual development based on similar attributes known to effect displacement rate and thereby removing a high level of uncertainty.

Key words: Gannet, displacement, offshore wind farms

RANGE EXPANSION OF THE GREAT CORMORANT THANKS TO BOOMING OFFSHORE WIND FARM DEVELOPMENTS IN THE NORTH SEA

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As a result of the limited water resistance of their plumage, Great Cormorants Phalacrocorax carbo cannot forage far offshore. They need to dry their feathers at loafing sites near the foraging area before being able to fly again longer distances. At sea, only human infrastructure can provide these places. For long, the only such offshore structures were buoys and measuring masts. However, in recent years, offshore wind farms (OWFs) seem to increasingly attract large numbers of cormorants. Planned large-scale OWFs in the (Dutch) North Sea (but in fact in all offshore areas within the geographical range of the species) could thus potentially lead to a significant range expansion of Great Cormorants. In OWFs, they would not only benefit from artificial resting places, but also from increased food availability due to fishing restrictions in OWFs. At the same time, the attraction to OWFs may also affect the number of birds that are posed with collision risk. Furthermore, wind farm developers perceive bird droppings as a health and safety issue. In the Dutch North Sea, the first OWF about 13 km off the coast is operational since 2007. Until this year, four more wind farms have been added about 20-25 km from the shore. In 2023, two more large wind farms will be developed about 18-30 km offshore, and further large-scale plans exist for the near future for many more large OWFs. We demonstrate that these large-scale OWF developments resulted in a significant offshore range expansion of cormorants throughout the years. First of all, we show based on long-term aerial and ship-based surveys in the Dutch North Sea that while cormorants had hardly ever occurred farther offshore before the appearance of the first OWF, the number of observations increased parallelly with the number of OWFs arising. We discuss that based on measured foraging ranges of breeding Great Cormorants tagged with GPS loggers before the development of any OWFs in the vicinity of their coastal colony such offshore distances have not been reached. Namely, despite a mean foraging distance of 20 km from the colony and mean of 50 km total distance of foraging trips, the average maximum distance of these trips was only 8 km from the coast. Finally, we provide the illustrate through the results visual observations that the numbers of cormorants are even higher inside OWFs than outside (48% difference), indicating a strong attraction effect of these offshore structures.

Key words: foraging range, attraction, aerial survey, GPS logger, OWF

IN VITRO EVALUATION OF EXPOSURE OF EARLY LIFE-HISTORY STAGE (ELHS) MARINE FISHES TO ELECTROMAGNETIC FIELDS (EMF)

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The rapid growth of marine renewable energy (MRE) installations means that submarine power cables are growing in number, with increasing potential to impact marine biodiversity, especially via electromagnetic fields (EMF). The 2-year CEMFISH project aims to study the impact of different offshore electromagnetic fields on the early life-history stages of marine fishes. The study was conducted at Marseille marine station, which enabled long term (3 month) experimentation. Four levels of EMF (0, 10, 100 and 500 micro-Tesla), corresponding to levels observed in situ at different distances from cables at MRE installations, were tested during 12 continuous weeks in four different experiments. Those levels correspond to 50 Hz fields in Alternating Current (AC). In addition, two experiments were conducted with Direct Current (DC) exposures at three levels (0, 100 and 500 micro-Tesla). Fish survival, growth and stress were surveyed over the experimentation period. Three different species were studied: seabass (Dicentrachrus labrax), European eels (Anguilla anguilla) and European salmon (Salmo salar); eels and salmon are known to be sensitive to EMF. Every week, body length and mass, and stress (based on measurement of opercular beat rate (OBR)) were measured. Seabass and European eels were studied in AC and DC currents. European salmon were studied only in AC currents. Fish sizes ranged from 20 mm at the start of experiments, to more than 100 mm after 12 weeks of growth. Results show no significant differences observed for fish survival, growth or stress between all levels of EMF for the three fish species. We found some slightly significant results for growth rates that we consider to be artefacts of the experiment. However, other studies should be conducted to explore the effects of EMF on migration and orientation behaviour of salmon and European eels to determine population-wide implications.
Key words: Electromagnetic field, marine fishes, AC&DC currents, in vitro long-term experimentation

HETEROGENEITY IN HARBOUR PORPOISE PRESENCE NEAR TWO FLOATING OFFSHORE WIND FARMS

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In recent years, significant advances in floating offshore renewable energy infrastructure have been made. The use of floating wind turbines is expected to increase globally, expanding rapidly into deeper waters, further from shore, within highly productive shelf seas. It is therefore crucial to understand species' responses and impacts at individual, population and ecosystem levels. The ecological significance of floating turbines, in terms of impacts (positive and/or negative) on mobile species such as the harbour porpoise, remains poorly understood but could be substantial based on current knowledge of fixed wind farms and other static structures such as oil and gas platforms. Harbour porpoise presence is often reduced during construction of fixed wind farms due to piling noise and vessel activity, although relative densities typically recover subsequently. However, data on porpoise presence and behaviour surrounding floating turbines are lacking. Due to differences in operational noise, with the sound signature of floating turbines less predictable due to movement of the structure's mooring components, the influence on animal behaviour might be different compared to fixed structures. Porpoise presence data were collected as part of the FORTUNE project (https://supergen-ore.net/projects/fortune) which collected underwater sound data at the Kincardine and Hywind Scotland floating offshore windfarms (Scotland, UK). Data were collected during early winter at Kincardine (November 2021 – January 2022, 9 MW Vestas turbines, semi-submersible platform) and spring-early summer at Hywind Scotland (May-June 2022, 6 MW Siemens turbines, spar-buoy platform) using automated click detectors (F-PODs). Detectors were deployed within each wind farm (distance to nearest turbine ~600 m at Kincardine, 300 m at Hywind Scotland) and at a secondary site outside of each farm (~1,500 m at Kincardine, 2,400 m at Hywind Scotland) to compare presence and behaviour at different distances from the turbines. Initial results indicate fewer porpoise detections closer to the turbines than at the distant sites for both locations, although overall patterns were similar between the close-by and distant sites. Results suggest porpoises may be displaced from operation, or that vocalisation is reduced near turbines; there is no evidence of strong attraction. Differences in presence between sites were observed, which could be a seasonal effect, related to habitat variables, differences in noise levels due to arrays/substructures, vessel presence, or a combination of these factors. This study is one of the first investigations of presence, foraging patterns and inter-site variability of a top predator at floating offshore wind farms.

Key words: floating offshore wind, harbour porpoises, top predators, behaviour, distribution

INTERACTIONS BETWEEN SEALS AND OFFSHORE WIND FARM CONSTRUCTION

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Many countries have set ambitious targets for renewable energy, with energy from offshore sources anticipated to form an important part of this; this has led to the proposed installation of many thousands of wind turbines in coastal areas. High levels of underwater noise associated with the installation of the turbine foundations has a range of potential impacts including hearing damage and behavioural responses. Here we summarise over a decade of research into the interactions between offshore wind farms and harbour seals (Phoca vitulina). We present the results of a range of studies of wild seal behaviour in areas where wind farms were being constructed. We deployed animal-borne GPS tags on 24 seals during 2012. Tags provided location and dive data, allowing investigation of their proximity to pile driving, and to estimate hearing damage in each seal. The closest range of individual seals to piling varied from 3.9 to 40.4 km and cumulative sound exposure levels (weighted for seal hearing) varied between 134 and 176 dB re 1 Pa2.s; although the prediction of auditory damage in marine mammals is a rapidly evolving field of research, based on published auditory injury criteria, these results suggest that low numbers (17%) of the seals received levels sufficient to cause temporary shifts in hearing sensitivity. Analyses of behaviour of seals during pile driving showed that there was significant avoidance of the piling activity by seals; within a distance of 25km, there was a 19 to 83% (95% confidence intervals) reduction in abundance. Further analyses of responses by individual seals to pile driving included summarizing metrics of seal movement (speed, direction, diving) using a multivariate statistical metric to objectively identify unusual changes in movement (responses). We quantified the response probability as a function of pile driving sound level using a Bayesian hierarchical model. Identified responses included increases in speed, increased variability in heading, and changes in dive behaviour during pile driving. The estimated p50 (sound level at which half of the population would have responded) was 175 (95% CI: 167-180) dB re:1µPa2.s. The results presented here show clear behavioural and physiological responses by seals to offshore wind farm construction; however, information on how responses vary with factors such as location, habitat type, and species, and how seals interact with offshore wind farms in the long term is critical to ensure that seals can co-exist with developments at the scales currently being envisaged for the industry.
Key words: Marine mammals, pile driving, construction, behaviour, physiology

HARBOUR PORPOISES AND OPERATIONAL OFFSHORE WIND FARMS; OCCURRENCE AND RESPONSES IN TIME AND SPACE

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With the ongoing development of offshore wind energy in the North Sea, a substantial part of the distribution of harbour porpoises (Phocoena phocoena) will overlap with offshore wind farms (OWFs) in the near future. Effects of the construction of OWFs on the distribution and ecology of harbour porpoises has received a lot of attention in research and impact assessments for many years, however, data on the presence of harbour porpoises in and around operational OWFs are relatively scarce. Gaining more knowledge on the spatial and temporal occurrence of harbour porpoises in OWFs is a prerequisite for adequate impact management. As part of ornithological monitoring programmes, around 150 visits to multiple OWFs in the North Sea were carried out between 2007 and 2022. Following standardized observation protocols for birds, marine mammal observations were also recorded during these visits. Additionally, harbour porpoises were recorded during Digital Aerial Surveys (DAS) in and around the operational wind farm Borssele in 2021. Commissioned by the Dutch Governmental Offshore Wind Ecological Programme (Wozep), we combined all harbour porpoise observations from these studies with the aim to study temporal and spatial use of operational OWFs. Harbour porpoises were seen year-round inside OWFs with highest abundances in winter, and animals were recorded even at close distances to wind turbines and platforms. Behaviour was not systematically recorded but foraging behaviour inside the wind farm area was observed on a small number of occasions. A comparison of observations in two nearby OWFs separated by a decade suggests an increase in the abundance of harbour porpoises in the area over time. Data of DAS indicates that the density of harbour porpoises in and around Borssele did not differ from their densities in a reference area north of Borssele. Furthermore, preliminary analysis of corridor use suggests that harbour porpoise densities are higher inside a wind farm corridor compared to the wind farm border or inside the wind farm area, although sample sizes are currently too small to draw any statistically significant conclusions. These data will be integrated with the data collected from the Wozep Passive Acoustic Monitoring project (Porpoise Network Borssele) and the harbour porpoise tagging pilot commissioned by Wozep and the Dutch Ministry of LNV. Based on data from various data sources we show when and how harbour porpoises use OWF areas, contributing to our understanding on the responses of and impacts on harbour porpoises to operational OWFs.
Key words: harbour porpoise, offshore wind farms, digital aerial surveys, temporal and spatial use

WIND ENERGY DEVELOPMENT IN LATIN AMERICA AND THE CARIBBEAN: RISK ASSESSMENT FOR FLYING VERTEBRATES

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Wind turbines occupy the altitude range of the airspace with the highest abundance of flying fauna, which can have negative impacts on wildlife species, particularly birds and bats. These animals may collide with turbines or associated power lines, suffer habitat loss, or be displaced. In this study, we provided an update of the scientific knowledge on the impacts of wind farms on birds and bats in Latin America and the Caribbean (LAC). In addition, we used available information on the distribution of threatened species to map hotspots of exposure to wind farm infrastructure. Finally, we used wind potential density to identify areas where wind industry development could pose a risk to threatened species. We identified approximately 857 wind farms, with more than 16,000 wind turbines in 20 countries. However, we found that with only 19 scientific papers investigating different impacts on bird and bat species, the amount of research on the impact of wind farms on flying fauna is still very limited. Six countries in the region studied the issue, with 11 articles in Mexico, five in South America and three in Central America and the Caribbean. The impact studies included 114 bird and 60 bat species, an insignificant number given the large biodiversity hotspot that the LAC region represents. The impact of wind farms on three species of bats classified as globally threatened by the IUCN, the Minor Red Bat (Lasiurus minor), the Red Fruit Bat (Stenoderma rufum) and the Lesser Long-nosed Bat (Leptonycteris yerbabuenae), was recorded. No studies identified globally threatened bird species affected by wind farm development. Still, our maps showed that there is high exposure to wind farm impacts for threatened bird species in Mexico, northeastern Brazil, the southern coast of Brazil, the coast of Uruguay, and central Chile. In addition, our results showed that the highest values of wind potential, where there are currently no wind farms, are distributed below 40° South latitude. These areas, which have not yet been greatly affected by wind energy development, could be prime locations for future wind farms, which could negatively affect the population dynamics and demography of species sensitive to these installations. Here, we highlight the urgent need for field surveys in the LAC region and provide not only overlay maps to identify the most sensitive current and future areas, but also a list of threatened species that may be affected now or in the future.
Key words: human infrastructure, airspace, renewable energy, aero-ecology, mortality

U.S. NATIONAL ANALYSIS OF BAT MORTALITY AT WIND ENERGY FACILITIES

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Goal: To meet climate goals, wind energy development is expected to increase in the coming decades. Concerns over the impacts wind energy infrastructure may pose to wildlife have risen as mortality from collisions of volant species have been documented. Though research for mitigating wind energy-related mortality is being conducted, some bat species continue to decline in the face of multiple stressors, including from wind energy generation. The current accepted metric for bat mortality resulting from wind energy generation is to use rated capacity as the primary predictor of bat mortality risk, often summarized as a mortality rate in bats per megawatt. This proxy is limited in its ability to accurately capture mortality risk to bats because it fails to characterize other aspects of wind turbine technology and advancement (such as the rotor swept zone) and ecological bat characteristics (such as abundance and habitat use, and their interactions). Our multi-agency interdisciplinary team analyzed facility-level mortality data from 260 U.S. wind facilities and over 500 reports to quantify the impacts of wind energy development on U.S. bat populations. Material and methods: We use a multivariate community N-mixture model to relate bat mortality to wind energy technology and spatial habitat and bat ecosystem characterizations. These covariates help explain the observed mortality counts, with mortality estimators (corrected for unsearched area and portion of year) serving as prior information on detection probabilities. Results: We identify which covariates have significant relationships with observed mortality and compare predicted mortality to observed mortality. Conclusion: Importantly, the fitted model moves beyond the current practice of using only megawatts to predict bat mortality risk and can be used to predict risk with greater accuracy, which will benefit conservation managers and decision makers.
Key words: population ecology, bat mortality, extinction risk, wind energy, Bayesian statistics

EFFECTS OF OPERATING AND PROPOSED OFFSHORE WIND FARMS ON COMMON GUILLEMOTS (URIA AALGE) IN THE SOUTHERN NORTH SEA

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The pressure for governments to massively reduce the greenhouse gas emissions is currently stronger than ever, and large-scale offshore wind farms (OWFs) are approved worldwide. Top predators are strongly affected by changes in the environment and by anthropogenic activities. The common guillemot (Uria aalge) is prone to interfere with OWF, because it is one of the most numerous seabird species in the world. We assessed the cumulative effect of all operating and proposed OWFs on guillemots in the German North Sea based on a long-term and large-scale dataset on their distribution and abundance. A 'before–after control impact' (BACI) analysis was applied within the framework of generalized additive models to estimate the relative change of the guillemot density in the area influenced by operating OWFs, as well as to evaluate the response range to the OWFs. Furthermore, two different analysis approaches were applied to estimate the potential effect of proposed OWFs on common guillemot occurrence: 1. The effects of operating OWFs revealed by the BACI approach were applied in combination with the current German plans for OWF implementation on the known distribution of common guillemots, 2. a combination of regression and mechanistic models was applied to also consider potential spatial reorganisation as well as natural and anthropogenic variables additionally influencing spatio-temporal animal abundance. If OWFs were implemented according to the current maritime spatial plan for the German Exclusive Economic zone, the OWFs would cover 13 % of the German North Sea. During autumn, the season when guillemot numbers are highest, the offshore waters of the German North Sea host approx. 90 000 individuals. The BACI approach revealed that guillemot density in autumn was significantly reduced up to a radius of 19.5 km around operating OWFs. Applying this disturbance distance to the current installation plans 70 % of the German North Sea would be affected for guillemots. Based on the two different analysis approaches investigating potential future OWF effects we estimate that 68 – 76 % of the common guillemots occurring in the German North Sea would experience habitat loss. Our study clearly illustrates the pressure to guillemots in the southern North Sea by an implementation of the current plans of the German government. The estimates provided here are highly relevant for marine spatial planning and management recommendations to decision-makers.

Key words: Cumulative effects, Habitat loss, Common guillemot

VULNERABILITY OF GOLDEN EAGLE POPULATIONS TO FATALITIES AT WIND ENERGY FACILITIES

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As renewable energy production expands across North America, regulatory guidelines often call for estimates of population level impacts of renewable energy-derived fatalities on wildlife species. However, such estimations are difficult and rarely accomplished. Here we implement a framework for estimating population level consequences of renewable energy development for an iconic apex predator with a circumpolar distribution. Our approach is unique because we first define the geographic origin of individuals killed at renewable facilities and then implement demographic models for those origin populations. An integral part of this assessment is defining the geographic origin of highly motile species killed at wind facilities. Previous studies have used stable hydrogen isotopes (δ^2H) for this purpose. However, the uncertainty associated with δ^2H-based estimates of geographic origin is typically large, making it challenging to use this approach to identify the origin of a given individual for species with multiple distinct breeding and wintering subpopulations. To overcome these challenges, we used a multi-isotope approach to geolocation, considering isotopes of δ^2H, carbon (δ^13C), and sulfur (δ^34S) to evaluate population of origin for Golden Eagles found dead at wind energy facilities in Wyoming. Subsequently, we used a Bayesian integrated population model to identify vulnerability of subpopulations of Golden Eagles to fatalities from wind energy development. Preliminary data suggest that the multi-isotope assignment process using δ^2H, δ^13C, and δ^34S resulted in substantially improved estimates of population of origin than with a single isotope alone. Demographic models identified widely varying levels of vulnerability among subpopulations, with notable differences between migratory and resident populations. Our approach illustrates the relevance of multi-element isoscapes to further classify population of origin or identify subpopulations of interest and how those origin data can then be used to assess vulnerability of species potentially affected by wind energy development. The tools we illustrate here are widely applicable to a range of different avian and chiropteran species that may be affected by fatalities at wind energy facilities.

Key words: anthropogenic effects, bird populations, wildlife mortality

CUMULATIVE IMPACT AND CATCHMENT AREAS OF LESSER KESTREL IN NORTHERN SPAIN INFERRED FROM POST-CONSTRUCTION FATALITY MONITORING.

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The Lesser Kestrel Falco naumanni is a small migratory falcon and its population experienced a rapid decline in Western Europe. The species occupies preferably the southwestern Iberian Peninsula in Spain and Portugal. It is rarely detected at migratory bottlenecks worldwide during its migrations. However, after the breeding season and prior to the autumn migration, its population develops a pre-migratory dispersal northwards in the Iberian Peninsula far from their areas of origin. We analyzed the fatality patterns at two joining regions (Aragón and Soria, Northern Spain) totaling 47,969 sq. km and hosting 140 and 44 wind farms where the species either breeds or is just a summer visitor respectively. We reviewed the post-construction fatality monitoring reports from which we extracted 175 and 57 fatalities in between 2003 and 2022. Spain extends from 43° latitude N to 36° in southern Andalusia. Secondly, we analyzed the ring recoveries available from the Spanish ringing Office, selecting Lesser Kestrels recovered or re-sighted in northern Spain coming from birds ringed in southern regions. Forty-three died because of any type of collision with human infrastructure, but five (11.62%) occurred at wind farms far from their breeding origin. Results showed that fatalities mostly occurred between July and October, with maximums in August and September (80-98.25%), regardless of happening near or away from the breeding areas. Near or within the breeding areas, fatalities also occurred between March and June (8-14%) but not in the dispersal areas. Results suggest that fatalities at wind farms may pass underestimated, having an effect on the population dynamics of the species as demonstrated in other countries, e. g. France. They involve both local and birds from colonies far away, impacting an area that extends beyond the footprint of single projects and beyond the Spanish distribution range of the species. Either pre or post-construction studies did not consider cumulative impacts on the Lesser Kestrel, requiring a broader approach rather than a project-by-project basis. This could be also reinforced by a not proper pre-construction monitoring studies, where the species would be undetected.

Key words: Lesser Kestrel, catchment area, population, migration

ENOUGH IS ENOUGH? DELIVERING SEABIRD COMPENSATION TO KEEP OFFSHORE WIND ON TRACK

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The UK is at the forefront of the development of offshore wind power and is second only to China in installed generating capacity. But the UK also hosts internationally important numbers of breeding seabirds, many of which are facing pressures from climate change, over-fishing and disease. The addition of predicted wind farm impacts has therefore raised significant concerns of adverse effects on many populations of these species. While individual offshore wind farms are rarely predicted to have significant population scale impacts on seabirds, collectively the predicted cumulative numbers of collisions for some species' populations have reached levels which the UK's statutory conservation advisors can no longer agree are acceptable. As a consequence, the UK Government has only awarded planning consent to recent offshore wind farms on the basis that their impacts on these species are fully compensated. This talk focusses on the delivery of required compensation for protected populations of two seabird species, kittiwake and lesser black-backed gull, in relation to the predicted cumulative collision effects from the Norfolk Vanguard and Norfolk Boreas Offshore Wind Farms, and the need to work very quickly to avoid delays in delivery of the 3.6GW of electricity from these wind farms. Although the outline compensation plans were agreed prior to the wind farms being consented, the actual delivery for both species was achieved in less than 12 months: the first steering group meetings were held in April 2022 and both compensation schemes were completed by February 2023. The process included agreeing implementation plans, designing appropriate structures, finding suitable sites and obtaining necessary permissions, developing monitoring protocols, appointing contractors and completing construction. Both compensation schemes were in place prior to the 2023 breeding season and are expected to be on track to deliver the required compensation before the wind farms are operational. Important lessons were learned and best practice suggestions are made to assist in achieving similar outcomes elsewhere.
Key words: Compensation, seabirds, collision risk

OFFSHORE WIND ENERGY SUITABILITY, ENVIRONMENTAL IMPACT AND CUMULATIVE IMPACT ANALYSIS – DELIVERED WITHIN THE MARITIME SPATIAL PLANNING PROCESS

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The Canary Islands are an ideal location for the development of offshore wind energy (OWE) due to their location in the Atlantic Ocean and strong winds. However, the development of this sector must take into account the potential environmental and social impacts, as well as technical and economic feasibility. The University Institute ECOAQUA initiated the PLASMAR (2017-2020) and PLASMAR+ (2020-2023) research and development projects to study the introduction of this novel sector and its impact on the marine environment, considering fragile ecosystems. To identify suitable areas for the development of offshore wind energy, a multiparameter methodology was developed. This methodology considers the environmental sensitivity of the area, restrictions related to marine conservation, oceanographic potential, land-sea interactions, and potential conflicts with current maritime and coastal activities. An extensive literature review was conducted on the environmental effects and changes that offshore wind energy can have on the Good Environmental Status (GES) described by the European Marine Strategy Framework Directive (2008/56/EC). An environmental impact assessment (EIA) checklist was developed to evaluate the compatibility of offshore wind energy developments with the maintenance of the GES of the marine environment. Finally, a system to calculate the Cumulative Impact Assessment (CIA) was developed to assess the impact of offshore wind energy developments on the existing pressures from other maritime sectors such as maritime transport, aquaculture, and mineral extraction. Studies, analyses, and related results were conducted over a Canary Islands marine area of 45,613.5 km2, supporting Maritime Spatial Planning within the archipelago and the Macaronesia European outermost region.
Key words: Offshore Wind Energy, Environmental Impact Analysis, Cumulative Impact Analysis

HIERARCHICAL ESTIMATION OF TURBINE-LEVEL MULTI-SPECIES BAT MORTALITY WHILE ACCOUNTING FOR HETEROGENEOUS SEARCH EFFORTS

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Goals. Mortality at wind facilities may be reported at various scales. Compared to aggregated reports of fatalities across wind facilities, data describing individual carcasses found during turbine searches can support fine-scale modeling of variability in search effort and turbine-level effects. Our research advances the science on assessing the impact of future wind energy development on bat mortality via a U.S. multi-agency interdisciplinary collaboration. Materials and Methods. We introduce a Bayesian multi-species N-mixture model to estimate monthly bat mortality at the turbine-level across multiple wind facilities. We apply our model to a dataset of regular turbine searches with heterogeneous search efforts across a group of wind facilities in Iowa. Our model includes standard estimates of imperfect detection by adjusting for search area, searcher efficiency, and carcass persistence probability over variable search intervals. However, we account for spatial, multi-species, and hierarchical variability in bat mortality via advanced methods integrated into a Bayesian framework that propagates all input uncertainties to final model predictions. First, by utilizing a layer of access roads from Open Street Maps and turbine locations from the United States Wind Turbine Database, we approximate the area of each search plot. We account for search effort by modeling the distance-dependent density of carcasses around a turbine and integrating over the search area to estimate the probability a carcass falls within the area searched. Additionally, we model the correlation between the observed species of bat fatalities at each facility via correlated random effects. While the ecological context of these correlations can be difficult to decipher, these effects allow the model to better estimate trends in mortality for bat species that are less often observed. Finally, we include a hierarchical parameterization to estimate the influence of facility and turbine-level covariates. We considered multi-scale covariates such as local land cover, habitat suitability, facility layout, and turbine design. Results. Variability in search effort, especially among heterogeneous road and pad layouts and full plot searches over variable search intervals, greatly

influences the total number of carcasses found at each turbine over time. Accurately accounting for this variability is more feasible at the turbine-level compared to aggregated reports of fatalities across facilities. Using our model, we can infer whether individual turbine characteristics have a disproportionate effect on bat mortality. Conclusions. Such an analysis may inform future decisions on turbine placement and design characteristics that can minimize the impact of wind energy on bat mortality.

Key words: bat, multi-species, turbine-level, mortality, estimation

HABITAT SUITABILITY MODELS AS A BASIS OF CUMULATIVE ASSESSMENT FRAMEWORKS

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Habitat suitability models form the basis of most cumulative wind farm effect studies on animals at sea. The spatial densities that the models predict give an indication of the spatial habitat use of animals and thereby the potential severity of disturbance by wind energy development per area. In this project, habitat suitability models are developed for a large number of seabird species in the southern and central North Sea, based on Dutch (MWTL) and international (ESAS) bird observation data. The habitat models are based on statistical correlations in space and time (INLA) between relevant co-variables (environmental factors) and observed seabird numbers. In addition to spatial density predictions, the models provide information about the reliability and statistical uncertainty regarding the predicted densities. In cumulative impact assessments for seabirds, spatial density predictions can be used to quantify potential numbers of casualties per area due to collisions with turbines and habitat loss due to wind farm avoidance. This information can then be used in the site selection process, to try to avoid overlap of wind energy development areas with essential seabird habitat. Moreover, the models provide insight in the ecological factors that are important for seabird habitats. Special attention is given in this project to the relation between fisheries activity and habitat suitability for the different seabird species, as fisheries patterns are expected to change drastically due to the deployment of offshore wind farms and the rising fuel costs. A thorough understanding of the relation between environmental factors, such as fisheries intensity, hydrodynamics and proximity of breeding colonies, and habitat use by seabirds is needed to provide future predictions of the effects of offshore wind farms on seabirds.

Key words: Habitat suitability models, seabirds, INLA, spatial density predictions

LIFE-CYCLE IMPACTS OF OFFSHORE WIND ENERGY DEVELOPMENT ON MARINE MAMMALS

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Wind-power farms are being developed and established at a rapid pace onshore and offshore, requiring large areas and impacting biodiversity. While renewable energy has beneficial climatic effects, investigations of the costs for biodiversity are often limited and made at a late stage in the development of wind farms. Here we adapt a recently developed life-cycle impact assessment (LCIA) method to investigate the impacts of offshore wind-power farms on marine mammals during the operational phase in the North and Norwegian sea. Impact pathways for habitat loss and disturbance are developed to characterise the potentially disappeared fraction of species for recently constructed and planned offshore wind farms. We utilised occurrence data on marine mammals in public data bases and use species distribution models to map species richness. Presence data were combined with data on environmental variables know to be important for predicting the relative occurrence rate for different species of marine mammals. Bathymetry, seabed slope, sea surface temperature and the concentration of chorophyll-a were included, and the resulting species-specific maps were combined to maps of species richness for marine mammals. This facilitates the evaluation of biodiversity consequences of different wind farms and facilitates the inclusion of effects on marine mammals as one of the criteria used when investigating consequences of suggested novel sites for offshore wind farms. Biodiversity impact assessments using LCIA could be an important tool for decisionmakers to reduce negative effects on biodiversity.

Key words: Underwater noise, habitat loss, seals, whales, wind energy

LIFE-CYCLE IMPACTS OF OFFSHORE WIND ENERGY DEVELOPMENT ON MIGRATING BIRD DIVERSITY IN THE NORTH SEA

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As offshore wind energy development increases it is vital that we have tools to assess the cumulative impacts to biodiversity across multiple sites. Life cycle assessments, often used to predict cumulative greenhouse gas emissions or other environmental impacts from industries, are a useful tool for assessing and comparing cumulative effects over a large scale. Previous work by May et al. (2020; 2021) developed life-cycle impact assessments (LCIA) to evaluate impacts of onshore wind energy on bird species richness. We have adapted this methodology to assess collision, disturbance and barrier impacts of offshore wind energy developments on migrating birds in Norwegian waters. Migrating birds, particularly species that regularly travel thousands of kilometres and already have very high energetic requirements, could be negatively impacted if multiple wind farms are sited within their migration paths. The potentially disappeared fractions of species (PDF) – a measure of the potential loss of species richness in an area – for each impact was calculated for modelled distributions of birds on migration, grouped taxonomically. Distributions were modelled using a Brownian bridge approach and based on ring recoveries from countries surrounding the North Sea Basin. PDF values were calculated for existing, approved, and planned wind farm developments separately and then summed for each category. Where site-specific turbine information was not available a mean turbine size of 6MW was used for existing wind farm developments and a 10MW turbine in approved and planned development areas. Our results show that collision, disturbance, and barrier effects for existing wind farm developments have the greatest impact on migrating raptors, gulls, and waterfowl species, similar to LCIA results for onshore wind development in Norway. Raptors are the group most impacted by collision effects, whereas waterfowl rank highest for disturbance and barrier effects. Maps highlight where cumulative PDF values for combined collision, disturbance and barrier effects are expected to be highest, both by group and for all migratory species combined. As the offshore wind energy industry in Norway is still at early stages of development, LCIAs could be a useful tool for comparing potential impacts across proposed sites as well as assessing the cumulative effects of large-scale offshore wind energy development. The LCIA presented here could also be easily updated as better data on bird behaviour at offshore wind farms becomes available.

Key words: Life-cycle impact, bird migration, species richness, offshore wind, North Sea

A BAYESIAN FRAMEWORK USING INLA FOR AN ECOSYSTEM-BASED CUMULATIVE EFFECT ASSESSMENT OF OFFSHORE WINDFARMS

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To alleviate climate change consequences, UK governments are pioneering offshore wind farms (OWFs) to achieve the goal of 50 GW by 2030. The North Sea is a dynamic ecosystem with strong bottom-up/top-down natural and anthropogenic drivers facing rapid climate change impacts. Therefore, to ensure the compatibility of such large-scale developments with nature conservation needs, effects must be evaluated through cumulative impact assessments (CIA). By excluding climate change impacts, the current CIA procedures are failing to identify links between oceanic drivers and ecosystem components, leading to high uncertainty in population-level predictions. This turns into highly uncertain ecosystem assessments with a limited understanding of impacts that manifest from fine-scale up through to ecosystem scales and therefore lacks the ability to inform future offshore wind leasing rounds. This study will present a Bayesian framework using Integrated Nested Laplace Approximation (INLA). Firstly, we will use predicted drivers of population trends which are the outcomes of ecosystems models run over a 30-year time series. Secondly, we will use a fine-scale spatial modelling approach involving INLA allowing analysis of high-resolution spatial information to assess cumulative effects. The modelling framework will enable data-driven relationships between lower ecosystem components, such as oceanic drivers changing with both climate change and offshore energy extraction and their predicted effects across all trophic levels up to top predator populations (e.g., seabirds). The proposed methodology will assess the corresponding population trends under climate change and OWF scenarios across spatial scales. As a case study, we will use the Firth of Forth in Scotland, UK, a location with internationally important seabird colonies where multiple OWFs (3.1 GW) have been consented. We will present results for Northern gannets (Morus bassanus), a generalist species whose population trends appear to be strongly linked to the oceanic driver: the Potential Energy Anomaly (PEA). PEA is an indicator of the levels of stratification and mixing and is predicted to change significantly with both climate change and the effects of introduced structures and wind energy extraction. The analysis will output ecosystem-level population trends and then finer-scale distributions with associated levels of uncertainty. Ultimately, our modelling framework will encapsulate the consequences of habitat change under climate change and OWFs from both colony level to regional population level for use in strategic CIAs, compensatory measures, and marine spatial planning.
Key words: marine spatial planning, climate change, Northern gannets, potential energy anomaly, dynamic Bayesian network model

WHAT'S FOR DINNER? BAT DIETS AND THE ROLE OF CROP PEST EMERGENCE IN BAT FATALITIES AT WIND ENERGY FACILITIES

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Although the ultimate drivers of bat fatalities at wind turbines are still not fully understood, active foraging at operating turbines by insectivorous bats put them at increased risk of collision with rotating blades. Wind energy facilities are commonly located in agriculture fields where bats can exploit periodic superabundant insect emergence events in the late summer and early autumn. Thermal imaging, acoustic monitoring, and bat carcass stomach content analyses show bats prey upon insects on and near wind turbine towers. Studies, including in agricultural systems, have shown a positive association between insect abundance and bat activity. To our knowledge, the hypothesis that superabundant insect emergences near wind turbines increase bat fatalities by creating efficient foraging conditions has not been explicitly tested. We conducted a systematic review for four common bat species diets in the Midwest and northern Great Plains. The aim was to synthesize existing knowledge across species; assess the extent to which these bat focal species consume crops pests; and evaluate the potential for crop pest emergence models to predict temporal and spatial patterns of bat fatalities in this region. The studies we reviewed indicated big brown bats and eastern red bats consume a variety of crop pests including some for which emergence models may be available. In contrast, there were few studies for hoary bats or silver-haired bats, and the dietary evidence available in the literature has insufficient taxonomic resolution to conclude that crop pests were consumed. To augment existing data and illuminate relationships, we recommend that genetic diet analyses for bats, specifically hoary and silver-haired, be conducted in the late summer and fall in this region. The results may provide additional candidate insect models to evaluate bat fatality predictions at wind turbines and clarify whether the superabundant insect emergence hypothesis warrants further investigation. If the emergence of crop pests can be correlated to bat abundance, predictive crop pest models have the potential to support or inform bat fatality minimization strategies. We will discuss the implications of these results and their relevance to bat populations and fatality minimization efforts beyond North America.
Key words: Diet analysis, foraging behavior, trophic interactions

REDUCING OPERATIONAL IMPACTS OF FUTURE WIND PARKS ON AVIAN FAUNA THROUGH STRATEGIC SITE SELECTION IN NORWAY

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As the world increasingly embraces renewable energy sources, wind power has emerged as a promising alternative to fossil fuels. However, the operation of wind turbines can have significant negative impacts on the environment and wildlife, particularly on bird species. In this study, we employed a life cycle assessment approach to estimate the potential impacts of planned wind power facilities in Norway on avian fauna during the operational phase. The expected effects on bird life were quantified as potentially disappeared fractions of native species for 13 taxonomic orders and for four major impact pathways, namely collision, barrier effects, habitat loss, and disturbance. The sensitivity of our estimates was assessed by performing a Monte-Carlo simulation and iteratively altering the number and exact locations of wind turbines, their rotor diameter, as well as varying estimates of species group specific collision probabilities and disturbance estimates. The results highlight that the impacts of wind power facilities on native avian fauna are location- and season-specific and vary based on the operational impacts considered. The study identified the worst, as well as least detrimental facilities, in terms of their potential impact on bird species and in relation to expected energy production. The findings provide recommendations for planning and future scenarios to minimize the negative impacts on bird species. Overall, this study provides a ranking of sites and valuable insights into the potential impacts of planned wind power facilities on bird species in Norway. The findings can be used by policymakers, developers, and stakeholders to make informed decisions about which of the planned facilities should be built in a way to maximize benefits while minimizing negative impacts on the environment and wildlife. The study contributes to the ongoing efforts towards a sustainable and responsible energy transition.
Key words: LCA, planning, bird impacts, decision-support

THE UNDERRATED CONTRIBUTION OF WIND ENERGY INFRASTRUCTURES IN LAND TAKE: AN EMERGING THREAT TO THE BIODIVERSITY AND ECOSYSTEM SERVICES OF NATURAL AREAS

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The ongoing climate crisis, along with the recent energy crisis that has been escalating in the EU since 2022, are continuously driving policies towards more sustainable energy sources. Wind is among the higher listed energy sources within the EU and national energy policy agendas. At the same time, the need for the establishment of protected areas for biodiversity conservation is also strongly addressed and incorporated into both EU and national policies. The increasing targets for renewable energy sources (RES), along with regulations accelerating their establishment may jeopardize biodiversity conservation efforts and consequently undermine climate change mitigation actions. Land use change, in the form of land degradation, natural habitat loss, deterioration, and fragmentation, is recognized as the top driver of biodiversity loss globally. The establishment of wind energy projects in remote areas is expected to increase the footprint of terrestrial surface modification in the form of land take. In this study we focus on Greece, a biodiversity hotspot, with a large proportion of mountainous remote areas. Many of these areas attract high investment interest due to their great wind potential, while at the same time, many of them are designated as Natura 2000 sites. In order to quantify the land take of wind farms in Greece, we digitized the generation of artificial land by 90 wind power stations constructed between 2002 and 2020 (1.2 GW). According to our results 7,729 m2/MW (3.5m2/MWh) of new artificial land, 148 m/MW of new roads and 174 m/MW of widened roads were generated on average. This size is 3.5 times higher than the global generic estimate of land consumption per annual power generation in an average year. The number and size of wind turbines, the absence of other existing infrastructures and the elevational difference across new access roads were the main factors that increased the generation of artificial land. Our study indicated an alarming trend of selecting mountains, forests and seminatural areas to sit wind power stations in Greece, indicating that spatial RES planning should consider the terrain and existing infrastructure, to minimize the ecological footprint of windfarms, while at local scale, proper quantification of land take should be included in appropriate assessments for sustainable investments.

Key words: land take, remote areas, landscape, biodiversity conservation, artificial land

PELAGIO: PHYSICS-TO-ECOSYSTEM LEVEL ASSESSMENT OF IMPACTS OF OFFSHORE WIND FARMS

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By 2050 it's estimated >400 GW of energy will be gathered by offshore wind in the North Sea alone. How will this increased anthropogenic use of our coastal seas impact already stressed marine ecosystems? And how will that same production of renewable energy offset risks of extreme climate change that, left unchecked, will increase biodiversity declines. An important effect of wind-energy extraction will be to reduce the amount of energy that would normally go into local ocean currents via surface stress, altering mixing. Conversely, there will be local increases in turbulence around turbine structures. Any change in ocean mixing may change the timing, distribution and diversity of primary production, the base of the food chain for marine ecosystems. This has knock-on-effects on the diversity, health and locations of pelagic fish that are critical prey species of commercial fish, seabirds and marine mammals. The displacement of seabirds and fishing fleets means they have potentially increased competition for fish. However, if OWFs are also de-facto marine protected areas and positively affect primary production, they may provide good habitat for fish population growth. So, what are the cumulative effects of current OWF developments and the thousands of additional planned structures? Do the physical, biogeochemical and ecosystem changes exacerbate or mitigate those resulting from climate change? The new PELAgIO project will address all of these questions through an inter-disciplinary, multi-scale observation and modelling framework that spans physical mixing through to plankton production, on to the response of fish and whole ecosystems. We will present how we will collect fine-scale data using the latest multi-instrumented acoustic platforms set beside and away from OWFs, complemented by autonomous submarine robots. The new approach to capture continuous and coincident data from physics to fish, over multiple scales and seasons will allow understanding of the changes to mixing and wind deficit impacts. This bottom-up, comprehensive approach will enable true calibration and validation of 3D ocean-biogeochemical modelling systems, from the scale of turbine foundations up to regional scales. These new data will also help to understand and quantify how OWF expansion might change prey fish availability to seabirds and mammals with the identified changes integrated into Bayesian ecosystem models. The outcomes of these models, run under different scenarios chosen by stakeholders, will enable the cumulative effects of ecological, social and economic trade-offs of different policy approaches for OWFs to be quantifiably assessed for present day conditions and under climate change.

Key words: Autonomous Platforms, Bayesian Ecosystem Models, Coupled FVCOM & ERSEM, Gliders, Habitat Risk Assessment

MODELLED IMPACTS OF OFFSHORE WIND FARMS ON PHYSICAL MIXING AND PRIMARY PRODUCTION IN STRATIFIED WATERS

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The rapid growth of renewable energy development in shelf seas has raised the need to assess the direct and indirect impacts of these new infrastructures on marine ecosystems. At least 260 GW of offshore wind farms (OWFs) are planned to be deployed in the North Sea by 2050 with very large-scale OWFs (fixed and floating) arrays being deployed in Scottish shelf waters in the next 10 years. The targeted regions contain a range of different hydrodynamic conditions, from mixed to seasonally stratified water columns, with many physical and biological processes predicted to be affected. The spatial extent and temporal differences (pre and post spring bloom) of these effects are uncertain but may impact whole ecosystems, from phytoplankton to top predators. To investigate the possible effects of wind energy extraction, we have started by modelling areas targeted for future floating and static wind farm deployments with good long-term baseline data. The region of Firth of Forth and Tay Bay (Scotland, UK) has extensive wildlife and exemplifies an ecological and economic area of interest for top predators (seabirds, mammals) and the fishing industry. We used a 3D hydrodynamic model (FVCOM) coupled to a biogeochemical model (ERSEM) to investigate the comparison of two modelled scenarios, one with and one without OWFs, in a period in which we have high levels in-situ data (March to July 2003) to validate the coupled model. Comparing these two scenarios showed an overall decrease in primary production before the bloom (-7%), with a maximum daily decrease of 6% from wind farm deployments. Positive and negative variations in plankton abundance (chlorophyll-a) did not linearly correlate to their distance from OWFs, and large variations were identified close to (1-2 km) as well as far (75 km) from the farms. The wind wake strengthened the stratification in 58% of the domain, positively or negatively affecting the primary production depending on the changing hydrodynamic regime (i.e. less to more strongly stratified). Overall, dipoles in sea surface height, temperature and salinity were observed distributed between coastal and offshore waters, centred at OWF locations. The date of spring blooms appeared delayed in less stratified waters, and subsurface concentrations of plankton increased in intensified stratified waters, exhibiting slight upwelling. This study shows that investigating the impacts of OWF is imperative to understanding fine scale effects which are likely to influence species (e.g. seabirds and fish) higher up the trophic chain.
Key words: ERSEM, FVCOM, marine spatial planning, oceanography, primary production

WIND REEF – TOWARDS A NET POSITIVE ENVIRONMENTAL IMPACT OF OFFSHORE WIND FARMS DECOMMISSIONING

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MOTIVATION: While major offshore wind farm (OWF) development projects are being developed to support the green transition, the first OWFs are reaching the decommissioning phase. OWF decommissioning potentially includes a broad range of options from "remove all" to "leave in place" with different levels of impacts on biodiversity. Throughout the lifetime of an OWF, the ecosystem around the wind farm structures often transforms into a more species-rich and diverse ecosystem as the foundations act as artificial reefs. Practically applicable methods for assessing anthropogenic impacts on marine biodiversity are essential to protecting and enhancing biodiversity. However, objective methods for assessing such impacts are missing, limiting the options for stakeholders and operators to consider marine biodiversity when planning OWF decommissioning. Furthermore, it will be necessary to understand the social perception of different decommissioning options to ensure support from society. GOAL: This project aims to help the decision-making process around OWF decommissioning by addressing the critical issues for biodiversity and social acceptance. METHOD: We investigate the social perception and acceptance across national authorities, environmental NGOs, fisheries, and civil society around decommissioning of OWFs. The social perception of decommissioning options and impacts on marine biodiversity is investigated through a survey shared with around 50.000 Danes. Other social issues of relevance are identified through interviews and workshops with NGOs, regulators, and fisheries. We will develop a Life Cycle Impact Assessment (LCIA) method enabling the assessment of impacts on marine biodiversity associated with the decommissioning scenarios considered for OWFs. Firstly, we have done a systematic literature review to identify and quantify key (positive and negative) impacts on marine biodiversity for different decommissioning options. The causalities between pressures, states, and impacts are organized in so-called "impact pathways", forming a basis for developing the desired LCIA method. Finally, we investigate how LCIA can be used as a tool to communicate and support the decision process. RESULTS PRESENTED AT CWW 2023: At CWW 2023, we will present the devel-

oped impact pathways and preliminary results from the survey showing the social perception of OWF decommissioning and its impacts on marine biodiversity in Denmark. The survey will also be used to show how the level of information provided on the topic influences the perception.

Key words: Marine biodiversity, offshore wind farms, decommissioning, life cycle impact assessment, social acceptance

PREDICT: PREDICTING SEASONAL MOVEMENTS OF MARINE TOP PREDATORS USING FISH MIGRATION ROUTES AS PREY AVAILABILITY IN THE NORTH SEA

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Seasonal distributions of seabirds and marine mammals are driven by the daily, weekly, and annual migration patterns of their prey (fish). Spatial and temporal variations in fish migration routes, especially important pelagic, zooplankton-eating species, may in turn, be driven by biweekly, seasonal and annual changes in the timing and locations of where new primary production is created in shelf seas such as the North Sea. There are a number of fine-scale oceanographic features that have been identified as important locations with very high and predictable primary production (i.e., foraging opportunities), including fronts with high gradients of density change (tidal and shelf edge fronts) and bank/trough areas where internal waves are created. Within the planning of future large-scale offshore wind developments in the North Sea, there is a growing need to understand where top-predator distributions will have increased probability of interaction with windfarms. However, existing environmental monitoring techniques are currently based on tagging studies or aerial/ vessel-based snapshot surveys, which generate high variance between individual species, seasons, years, and development sites. In collaboration with the University of Aberdeen, Ørsted, and the Environmental Research Institute at the University of the Highlands and Islands, the PREDICT project aims to investigate these temporally ephemeral, but recurring fine-scale oceanographic features to predict mechanisms of variability in pelagic fish migration patterns in the North Sea. Using a Bayesian spatial modelling approach involving Integrated Nested Laplace Approximation (INLA), we bring together multiple datasets (e.g., ICES length-at-age and NEODAAS satellite frontal data) to investigate the years, regions and finer-scale features to recreate fish migration patterns of four pelagic species: Atlantic herring Clupeas harengus, Atlantic mackerel Scomber scombrus, European sprat Sprattus sprattus and sandeels Ammodytes spp. This approach will enable us to generate dynamic seasonal maps of overlap for the four species to elucidate spatio-temporal trends in growth rates to enable a tracking of annual cohorts with a greater degree of precision, thereby allowing a greater understanding of possible spatial effects driven by climate change. By focusing on these pelagic fish species, which are focal prey for many seabirds and marine mammals, the creation of individual and combined migration maps will help us to identify where locations of future offshore windfarms may overlap with fish high use areas; thus allowing for locations of high risk during the annual cycle of fish movements to be identified.
Key words: pelagic fish, migration, top-predators, oceanographic features

SYNTHESIZING MULTI-SCALE RELATIONSHIPS AMONG FORAGE FISHES AND MARINE PREDATORS IN THE NORTHWEST ATLANTIC OCEAN TO INFORM OFFSHORE WIND SITING

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Pelagic forage fish are key species in marine ecosystems, providing critical resources to upper trophic-level predators. Offshore wind energy development alters marine food webs and predator habitat use, and a better understanding of predator-prey relationships is needed to quantify and forecast the potential effects of ecosystem change. Understanding the magnitudes and scales of trophic interactions is vital to describing these marine communities, and the roles environmental conditions play in driving community dynamics. Here, we synthesize results from a multi-faceted project quantifying the relationships between forage fish and marine predators in the Northwest Atlantic Ocean across multiple Wind Energy Areas. This project used marine surveys and individual tracking studies to assess multi-species spatiotemporal relationships. Dynamic surface and subsurface environmental conditions were drivers of both species-level forage fish distributions and the densities of multi-species forage fish surface aggregations – which are considered indicators of prey availability for surface foraging predators. Among the several predictors that emerged as influential, surface currents and water column stratification were particularly important in predicting surface aggregations of forage fishes. Seabird telemetry models indicated that water depth, surface temperature, and chlorophyll a were primary drivers of seabird foraging behaviors. While the importance of these variables in driving forage fish distributions varied, seabird foraging habitat correlated spatially with forage fish aggregation density, indicating a link between movement behavior and prey availability. Moreover, we found a spatial correlation between forage fish aggregations and marine predator distributions from digital aerial survey data. Density models estimated that forage fish aggregations have strong relationships with aerial predators (gulls and terns) and subsurface predators (piscivorous fishes and delphinids). These relationships varied across seasons, with the strongest correlations between predator abundance and forage fish distributions occurring in the summer near freshwater inputs. Finally, we assessed the annual trends in forage fish and seabird distributions from 2003-2019. The effective area of seabird distributions tended to decrease over time with some detectable range shifts. Given prior evidence of forage fish range shifts, this suggests links between long-term trends in seabird and forage fish distributions. Together, these studies suggest complex relationships between marine predators and prey that

must be accounted for when parsing the confounded effects of offshore wind energy development on marine wildlife. We present examples of how to incorporate these relationships into project siting and incorporate multi-species dependencies into forecasting of ecosystem change.

Key words: forage fish, seabirds, species interactions, movement, siting

ECOSYSTEM APPROACHES TO DEAL WITH THE NEXUS OF TRADE-OFFS BETWEEN OFFSHORE ENERGY AND FISHING WITHIN THE CONTEXT OF CLIMATE CHANGE

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The UK is the current global leader in offshore wind with 10.4 gigawatts (GW) installed and a commitment to increase its capacity to 50 GW by 2030. Therefore, decarbonising the UK energy supply through increases in offshore wind will require an extremely rapid increase in the use of information on the nexus of the implications of trade-offs between both direct and indirect environmental effects, as well as spatial conflicts with other marine uses like food production (fisheries) and marine protected areas. The interlinked effects of changes from the introduction of structures, extraction of energy and displacement of fishing actives on the physical environment up through the entire marine ecosystem are needed to provide accurate estimates of cumulative effects of ecological, social, and economic trade-offs. We will present an ecosystem modelling and assessment approach that captures evidence-based impacts of climate change and marine uses on ecosystems and socio-economic impacts. Physical and biogeochemical outputs from 3D oceanographic models, created from in-situ measurements along with existing long-term biological measurements will be used to develop the dynamic Bayesian network ecosystem model. The model allows for the multiplicity of interactions amongst different ecosystem components (e.g., physical environment through to plankton, zooplankton, fish, and top predators), therefore, the habitat effects of offshore wind will be upscaled across different spatial scales (regional vs shelf-wide). By using prior information on changes over 30 years, this approach also incorporates climate change trends and measures whole ecosystem, as well as individual species population level trends. The methods therefore can assess changes in socio-economic value in response to offshore wind deployment scenarios as well as climate change. An example of a specific case study that will be presented is the “costing” of fisheries displacement from ORE developments in the North Sea. A choice of scenarios framed around climate change (e.g., “business-as-usual”) and fisheries (e.g., increase vs decrease in fishing pressure) is being co-designed with input from stakeholders. Through the scenario analysis, outputs in a range of ecological (e.g., stock biomass in kilograms) and monetary (e.g., Gross Value Added) metrics across a range of spatial scales and their predicted changes over time will be produced. The outputs of population trends in combination with risk maps of ecosystem-level and socio-economic change will provide strategic advice and policy support on the balance of benefits and trade-offs between marine uses to deliver long-term environmental and energy sustainability as well as economic benefits.

Key words: dynamic Bayesian network model, ecosystem functioning, cumulative effects, marine spatial planning

A COMPARISON OF PREDICTED BENTHIC HABITAT DISTURBANCE BETWEEN BOTTOM-CONTACT TRAWLING AND FLOATING OFFSHORE WIND ENERGY ALONG THE US WEST COAST

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Floating wind energy development presents a new use of the offshore marine environment. Some stakeholders have expressed concern on how this new technology may affect benthic habitats, especially those necessary to fish for spawning, breeding, feeding, or growth to maturity (also known as Essential Fish Habitat). Energy infrastructure such as anchors, cables, and electrical service platforms will directly impact the seafloor during construction of a floating offshore wind project. Using data on the spatial extent of impacts from offshore projects with similar components, we estimate that a generic 900 MW windfarm off the US West Coast would directly disturb approximately 130 sq km of soft sediment habitat, primarily from the installation of transmission cables. To put this in context, we compared this level of seafloor disturbance to that generated by commercial fishing vessels that use bottom trawls to harvest marine species. Using vessel monitoring system data that tracks the offshore spatial position and speed of a majority of trawlers along the US West Coast, we estimate that fishers will directly disturb approximately 23 million sq km of the seafloor during the lifetime of an offshore wind project on the US West Coast (~33 yrs). Thus, the spatial extent of direct seafloor impacts from a generic floating wind energy project is expected to be approximately 0.001% of the extent generated by commercial fishing activities. Two noteworthy indirect effects to seafloor habitats will also occur from an offshore wind energy project: (1) an artificial reef effect from the submerged portion of marine energy infrastructure, and (2) a de facto marine protected area effect due to the preclusion of trawling from inside a floating wind energy installation. Both indirect effects are likely to increase the local biomass and biodiversity of marine benthic habitats.
Key words: Floating Wind Turbines, Seafloor Disturbance, Marine Protected Area, Commercial Fishing, Artificial Reef

UNDERWATER NOISE IN AND AROUND A DUTCH OFFSHORE WINDFARM DURING CONSTRUCTION AND OPERATION

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The Southern North Sea is a busy area in which soundscapes are dominated by the noise emitted by vessels. The countries bordering this sea have ambitious plans for the development of offshore wind farms in the coming decades, a development that could impact the soundscape characteristics in the area and subsequently affect marine ecology. As part of the integral research program WOZEP (Offshore Wind Ecological Programme) and to study the impact of underwater noise on harbour porpoise (Phocoena phocoena), sound levels were monitored in- and around the Dutch Borssele offshore wind farm in both the construction- and operational phase. During the construction phase in 2019-2020, underwater sound levels were measured at seven fixed locations, with measurements continuing in the operational phase for five years starting in 2021. Sound pressure levels were analyzed in decidecade frequency bands per second for all measurements, in agreement with defined standards in the JOMOPANS project. In the construction phase, highest sound levels in the windfarm area were associated with pile driving activities, which occasionally exceeded background noise levels up to 30 km distance from the installation location. Outside the wind farm, underwater sound levels were primarily dominated by vessel noise. Inside the operational wind farm, sound levels were lower and consisted of both vessel noise and operational wind turbine noise. Results show that operational noise emitted from the wind turbine foundations (8 – 9.5 MW) impact a larger area than was shown in earlier studies with smaller turbines. The presented unique dataset provides insight into the underwater soundscape in an offshore wind farm during both the construction and operational phases, insight that is essential in determining the environmental impact of the upscaling of offshore wind development in the North Sea.
Key words: underwater noise, OWF, measurements, MSFD

PRELIMINARY INVESTIGATION OF OFFSHORE WIND ENERGY SITES IN THE GERMAN EXCLUSIVE ECONOMIC ZONE

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This abstract describes the preliminary investigation of offshore wind energy sites in the German Exclusive Economic Zone conducted by the Federal Maritime and Hydrographic Agency (BSH). The BSH starts a process of preliminary investigation of sites after the site development plan has determined areas for offshore wind energy. The preliminary investigation of sites comprises the biological marine environment, subsoil, wind and oceanographic conditions as well as traffic suitability. The assessment of potential environmental impacts is of particular interest in the development of offshore wind energy. The aim of the preliminary investigation of sites is to obtain and publish relevant information prior to the tendering procedure and construction of wind farms. Except for traffic suitability, all investigations involve offshore sampling campaigns. We present an overview of recent site investigation activities in the German North Sea and Baltic Sea, with a focus on the biological marine environment. Our investigations involve ship-based and airborne surveys to identify the presence and spatial distribution of protected assets: Marine mammals, demersal fish, benthic species, biotopes, bats, seabirds and bird migration. Sampling for benthic species and fish is carried out in autumn, and spring & autumn of the consecutive year. The occurrence and spatial distribution of harbour porpoises, harbour seals and grey seals are determined in ship-based and airborne transect counts. The habitat use of harbour porpoises is continuously recorded with hydro-acoustic measurements (POD stations). Seabirds and marine mammals are counted together on monthly ship transects. The ship-based counts are supplemented by 8-10 flight transects with a HiDef video system that allows for thorough digital analysis. Migratory birds are recorded from the ship with radar. Species are identified by supplementary visual observations during the day or by flight call recordings at night. Migration intensity, flight height and flight directions are recorded. When recording migratory birds and seabirds, special attention is paid to species which are protected in accordance with national and EU regulations. Therefore, the individual species are identified. Marine mammals and avifauna surveys take place for two successive, complete annual cycles. The results of these investigations are used to examine the suitability of offshore wind energy sites. The BSH publishes survey data, summary reports, environmental assessments and the suitability assessment on the PINTA-Data Hub. We present a detailed account of our investigations and the results obtained and show how to navigate the PINTA-Data Hub for all publicly available information.
Key words: site investigation, environmental assessment, offshore, biological sampling, public data

FIRST PROVEN EVIDENCE THAT REDUCING WIND TURBINE ROTOR SPEED MAY REDUCE SIGNIFICANTLY COLLISION RISK FOR APPROACHING MILVUS MILVUS

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Reducing bird fatalities is a pressing concern for the global wind energy industry and requires operational solutions that also ensure sufficient power production. One solution available on the market is the Safewind® technology, a camera-based device that detects and tracks birds in approach and actively controls turbine rotation speed. Studies suggest rotor speed to be one of the key variables that influences collision risk for birds in windfarms (Band et al., 2007, Marques et al., 2014, Shimada et al. 2021). Our aim was to investigate whether Milvus milvus (Red kites) can better see and avoid blades when blade tip speed is within their natural flight speed range, which is up to 76 km/h (Burderer et al., 2001). We have compiled a unique dataset, leveraging all the recorded detections, rotor crossings and collision events of Red kites and undetermined Milvus (Milvus sp.) during a four-year period (2019-2023) within 251 Safewind®-equipped turbines across Europe. Among our 400'000 video detections with associated blade tip speed, we observed more than 700 rotor crossings and 30 collision events. Our statistical analysis revealed that the proportion of rotor crossings was significantly lower when blade tip speed was above 76 km/h (McNemar's Chi-squared test, p-value <2.2e-16), consistent with a natural avoidance behaviour. Moreover, 96% of lethal collisions occurred above 76 km/h, with a tenfold increase in mortality when rotor crossing occurred above this threshold. Additionally, 92% of lethal collisions by Red kites and Milvus sp. occurred above 110 km/h. The analysis of the 30 collision events recorded by Safewind® revealed that collisions can occur at very low speed (32 km/h), and can be nonlethal, including at high blade tip speed (>270 km/h). These observations could be considered while developing future biodiversity protection policies. Some synchronous wind turbines have cut-in speeds that are close to the above-mentioned thresholds. Our results also support the idea that a complete shutdown of such turbines may not be required to reduce significantly collision risk for Red kites. Instead, reducing blade tip speed down to the cut-in speed threshold in case of approaching birds could help to significantly reduce both collision risk and power losses. To our knowledge, our study is the first to provide compelling evidence that real-time detection-reaction systems that lower rotor speed are effective in mitigating the risk of Red kites collisions. Moreover, a complete stop of turbines may not be necessary.

Key words: Red Kites, Collision risk, Curtailment, Rotation speed

MEASURING FLIGHT BEHAVIOR OF CORMORANTS WITH A DEDICATED 3D BIRD RADAR TO DEVELOP SHUTDOWN DECISION RULES

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In the first half of 2022, construction started on the 24 wind turbines of the new windfarm 'Windplanblauw' in Lake IJsselmeer in the Netherlands. These nearshore turbines will become operational at the end of 2023. It was only recently discovered that Great Cormorants (Phalacrocorax carbo) have established a new breeding colony close to this windfarm, that held an estimated 900 breeding pairs in 2021. Most of the wind turbines will be positioned within the foraging range of cormorants from this colony and a smaller number of turbines is likely to be positioned within the daily flight routes of commuting cormorants. Lake IJsselmeer is a strictly protected Natura 2000 site (Special Protection Area), designated amongst other things because of its internationally important numbers of breeding cormorants. However, numbers of breeding cormorants have been steadily decreasing over the last decade, leading to the species' poor conservation status in Lake IJsselmeer. Therefore, conservation scientists, local government and the windfarm developer have shown great concern for the potential negative impacts of the new windfarm on this colony due to the potential for high levels of collision-related mortality. A study to monitor flight behavior of adult cormorants in the nearshore project area was carried out in Spring 2022. This study aimed to understand area use, collision risk with the planned wind turbines and the need for additional mitigating measures in the windfarm such as shutdown-on-demand techniques. Here we present the results of a four-month study with a 3D bird radar Max® (Robin Radar Systems), which continuously collected flight routes, intensity, speed and altitude of birds passing through part of the nearshore wind farm area. During weekly field observations, many thousands of flight tracks recorded in 3D by the radar could be identified as being either from cormorants commuting between the breeding colony and the lake or from other bird species. With this validated dataset and machine learning we successfully developed an algorithm to extract additional tracks out of the huge radar dataset that also belonged to cormorants. We measured detailed flight behavior of a huge number of cormorants within and around the area of a future wind farm, including spatial and temporal density patterns and flight height profiles at high spatial and temporal resolution. We discuss how this information can inform stakeholders to decide on the necessity of, and choice of, mitigating measures to prevent collisions, including a precise definition of decision rules for potential shutdown.

Key words: Cormorants, radar ornithology, machine learning, mitigation

EFFECTS OF THE USE OF NOISE-MITIGATION DURING OFFSHORE PILE DRIVING ON HARBOUR PORPOISE (PHOCOENA PHOCOENA)

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In the southern North Sea, offshore wind farm construction usually requires hydraulic pile driving resulting in high levels of impulsive sound. Despite recent advances in noise-mitigation technology, harbour porpoises (Phocoena phocoena) respond to this pile driving over a period of hours to days per driven pile, depending on the distance at which the animals were disturbed. We used passive acoustic monitoring (PAM) datasets from 2016 (predating noise mitigation requirements) to 2020, including the construction periods of four offshore wind farms, to determine whether noise mitigation measures applied during the construction of offshore wind farms influenced the likelihood of detecting harbour porpoise before, during and following pile driving in the Belgian part of the North Sea (BPNS). Reductions to the spatial and temporal extent of avoidance of the construction area by porpoise were observed when noise mitigation was applied. Without noise mitigation, mean detection rates of porpoises reduced up to 15-20 km from the pile driving location. With noise mitigation however, mean detection rates of porpoises reduced to a lesser extent and this reduction mainly took place at 0-10 km from the pile driving. In the immediate vicinity of the construction site, the reduction in porpoise detection rates started prior to the pile driving suggesting the presence other sources of disturbance in this area during the construction. Our results suggest that efforts to reduce the impact of underwater noise generated by future offshore wind farm construction on marine life should aim to limit not only the noise levels generated but also the overall duration of the construction period.

Key words: harbour porpoise, noise mitigation, offshore wind, underwater sound

DO LARGE RAPTORS KEEP THEIR DISTANCE FROM THE ROTOR SWEPT-ZONE WHEN USING AUDIO OR STROBE DETERRENT SIGNALS?

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The dynamic development of wind energy requires the simultaneous implementation of effective systems minimizing the risk of collisions between birds and wind turbines. Data on collision avoidance behavior of big raptors with wind turbines is limited. Especially when it comes to the use of detection-reaction systems that enable taking actions to trigger a collision avoidance reaction, such as emitting sound or light signals. We have analyzed the data from BPS detection – reaction systems installed on four wind farms loceted in: north Spain and in north Germany. The specific feature of the BPS system is that the cameras are in stereoscopic set up, enabling 3d location of bird, distance, altitude estimation and size classification. BPS undertakes actions depending on distence from the turbines: strobo deterrent, audio deterrent, stopping the rotor. We used data recorded by the systems on the red kite Milvus milvus, white-tailed eagle Haaliaetus albicilla and griffon vulture Gyps fulvus. All birds recorded by the systems have been tagged to species by qualified ornithologists. We analyzed data of raptors moving near wind turbines to identify whether birds avoided the turbines as a result of the use of strobe and audio-based scarer mods. At the moment, the available data do not allow for the formulation of unambiguous conclusions indicating the level of effectiveness of using this type of solution in minimizing the risk of a collision. However, it cannot be ruled out that in the case of white-tailed eagle the strobe signal is a warning signal to keep them out of the zone immediate collision risk (swept zone). Data from Germany showed that share of birds whose movement did not activate the STOP signal after activating the strobe signal was 18.5%. In the case of a kite it was only 4.5%. Data from Spain showed that 23% of griffon vulture flying near the turbines didn't active the STOP signal after activating the audio signal. Our findings suggest that in the case of the white-tailed eagle, the use of strobe signals and in the case of the griffon vulture, the use of acoustic signals may be a way for these birds to avoid collisions. Further tests and analyzes are needed regarding the use of sound and light signals in different locations and for wind projects with different parameters of turbines.

Key words: avoidance behavior, protecting big raptors from colliding with turbines, audio and strobo signals, detecion-reaction system for protecting birds

THE IMPORTANCE OF ADDRESSING DISAGREEMENTS BETWEEN NOMINAL AND EFFECTIVE TREATMENTS DURING BAT MORTALITY MINIMIZATION VALIDATION STUDIES

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As the wind energy industry grows, so too does our need for effective and low-cost bat mortality minimization solutions. Despite knowledge gaps in our understanding of what drives bats to collide with spinning turbines, minimization solutions have shown success during validation studies. Curtailment has been consistently effective, reducing bat mortality from 33%–79%, depending on the curtailment scenario and species present. Several validation studies have demonstrated deterrent solutions, specifically ultrasonic deterrents, to be effective, but overall, more variable compared to curtailment solutions. Further, a study combining curtailment with ultrasonic deterrents produced encouraging results, finding that adding ultrasonic deterrents to turbines that were designated to curtail, significantly reduced mortality rates compared to curtailment only turbines. Despite positive results, the strength of inference achieved with validation studies is limited by methodological constraints associated with appropriately assigning fatalities to treatments. Because of the temporal separation between when a bat collides with a turbine and when it is discovered during a ground-based carcass survey, we must assign carcasses to a treatment that ran during the prior night(s). This process may introduce errors at multiple stages. First, for studies that rotate treatments among turbines, mortality surveyors must be confident that carcasses are 'fresh' such that mortalities are correctly assigned to the treatment from the previous night(s). Second, we must reconcile any misalignments between how we assign treatments and how we implement treatments (e.g., turbines assigned with a deterrent treatment may be implemented as another treatment when deterrent devices are not operating as designed). Finally, for curtailment solutions, it is critical to recognize that measured effects are a function of not just the treatment as implemented but the proportion of the night the treatment is realized (e.g., if wind speeds are greater than the curtailment treatment cut-in speed for the entire night, we cannot expect there to me any differences in mortality reduction relative to control turbines). Using a dataset collected between June and October 2017, that rotated 3 treatments (Deterrent Only, 5 m/s Curtail only, and 5 m/s Curtail & Deterrent) and 1 control condition across 16 turbines each night, we explored the importance and implications of accounting for potential errors in assigning fatalities to treatments. We present preliminary results comparing the mortality associated with error-corrected treatments and control conditions highlighting how the measured effect of a treatment (mortality) greatly depends on site specific implementation.

Key words: Mitigation, Validation Studies, Methods

DEEP LEARNING FOR MARINE MAMMAL MONITORING FROM UNDERWATER ACOUSTIC DATA AT OFFSHORE WINDFARM SCALE

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The increasing number of Offshore Wind Farms (OWF) raises key environmental and societal issues as for their impacts on wildlife. In this context, monitoring marine mammals along with information on their environment - i.e. underwater noise - throughout the OWF life cycle is crucial. Passive acoustics is used worldwide for multi-year monitoring of marine mammals. Dealing with large audio recordings raises the need to automate the detection of acoustic events. The objective of this study is to evaluate the performance of state-of-the-art deep learning models to detect and classify marine mammal sounds. A broadband hydrophone, deployed for three weeks at the Fécamp OWF in the English Channel, recorded the underwater soundscape including sounds from marine mammals occurring in the area. To visualize these sounds, we computed time-frequency images (spectrograms) of 15 seconds duration each. From the latter, a total of 2616 dolphins (D) and 2223 porpoises (P) sounds were manually annotated, including different types of sounds: Click-Trains (DCT: 2045, PCT: 2147), Buzzes (DB: 254, PB: 76) and Whistles (DW: 317). The spectrograms were split into training and validation datasets, with one half including manual annotations and one half with only background noise. We trained a Faster R-CNN model to detect and localize marine mammal sounds in the spectrograms as well as classify them by species and sound types. We used three model configurations: (1) overall detection of marine mammals (presence vs. absence) ; (2) detection and classification of species (two classes: dolphin, porpoise) and (3) sound types (five classes: DCT, DB, DW, PCT, PB). For the simplest configuration (1) 9% of marine mammal sounds are missed, and 26% of detections are false positives. For the two others, 25% (config. 2) and 32% (config. 3) of marine mammal sounds are missed; 10% (config. 2) and 11% (config. 3) of detections are false positives. The more complex the model, the lower the performance. The fewer missed detections, the more false detections, and vice versa. Several model parameters can be adjusted to trade off missed detections and false positives which need to be carefully thought and adapted to the problem. For instance, the first model would be particularly relevant for marine mammal detection during OWF constructions. The second and third would be more suitable for long-term studies and ecological inferences on the species. These models are promising to monitor the presence and behavior of marine mammals throughout the life cycle of the OWF.

Key words: ecoacoustics, marine mammals, deep learning, object detection, offshore windfarms

GIS MODEL OF SPATIAL AND TEMPORAL DISTRIBUTION OF WHITE STORK MIGRATION OVER THE BALKAN PENINSULA - APPLICABLE TOOL FOR WIND FARM DEVELOPMENT

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The white stork (Ciconia ciconia) is an excellent model for studying the spatial distribution of soaring bird species during seasonal migrations. The species is numerous, migrating in flocks with typical soaring type of flight in high number over the temperate zone of Europe including Balkans. We apply QGIS processing tools to study the spatial and temporal distribution of this typical soaring species over the Balkan Peninsula. Data are extracted from all available public sources. The results of 13 GPS tracking studies are analyzed. Over 740000 detections of white storks on the territory of the Balkans collected between 1991 and 2022 were included in the analysis. The height of the white stork migration was estimated for 630165 fixed points used in our analysis. We test our model by simultaneous visual observations at 4 observation points and investigate different hypotheses about the spatial and temporal distribution of the soaring birds in terms of typography, prevailing winds and phenology. Spring migration is concentrated over 10 days with a peak on the first day of April. Autumn migration is concentrated in August with a distinct peak at the end of the month. White storks migrate over the Balkan Peninsula between 100 and 3200 m.a.g.l. The mean flight altitude is 535 m.a.g.l. Obtained by our QGIS analysis heat map of migrating white stork density is supported by simultaneous visual observations. Our simultaneous observations support the GIS model of white stork migration in terms of density distribution over the area. The visual observations differ significantly in estimated by observer altitude of flight and obtained by GPS accurate altitude. The general distribution of available GPS tracking data indicates a strong preference for lowland areas by soaring birds. Prevailing winds distribute soaring birds randomly over lowland areas with strong seasonal variations in local density. The location of mountains in the Balkan Peninsula determines the general shape of the distribution of White Storks during migration periods. The second important topographic effect is related to the coastlines of the Black and Adriatic Seas. Seasonal fluctuations may exacerbate the topographic effects and are responsible for significant concentration of birds at different hotspots in spring and autumn. Our data show the temporal effect of such hotspots in typical bottlenecks of bird migration. Our model can be used in the planning of wind farms in Bulgaria and on a larger scale in the Balkans.
Key words: soaring bird, GPS model, bird migration, wind farms

AUTOMATED IDENTIFICATION OF BIRD SPECIES USING FLIGHT PATTERN

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As wind energy expands, the issue of bird strikes becomes ever more prevalent. Currently, an effective strategy is to switch off turbines when a vulnerable bird is identified in the vicinity. Species identification is either done by human workers or using camera systems that classify species by flight path. This project aims to test the potential of using flight pattern to identify species instead, as this has yet to be investigated, with the possibility of expanding the application to identifying behaviour or even the health of a bird. Flight pattern focuses on the actions of a bird in flight, particularly the ratio of flapping to gliding motion, and the frequency of upstroke and downstroke motion when flapping. The system developed, formed of three models, has an accuracy of 86.36%, a precision of 89.77% and a recall of 86.36% when classifying four species: Red Kite, Kestrel, Sparrowhawk, and Black-Headed Gull, which were chosen as representatives of four types of flight pattern. The species classification only required a small amount of training data to achieve promising results, suggesting that flight pattern can be a useful tool in improving the reliability of species classification in the vicinity of wind farms. Further data collection and algorithmic development could allow identification and behavioural classification for more species, in more diverse scenarios. Ultimately, we envision that flight pattern could be used alongside other information, such as location, colour, wing shape, and flight path, to facilitate more effective and robust bird strike prevention systems.

Key words: species identification, bird strikes, machine learning

PILOT STUDY OF AN AUTOMATED BIRD PROTECTION SYSTEM IN A GERMAN WIND FARM

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How to balance expected energy transition and biodiversity? A promising solution might be the use of bird protection systems (BPS) with an automated wind turbine stopping procedure. BPS were recently included in the German law as a potential mitigation measure, but a standardized permitting concept is still missing. This is due to the limited technical properties of older BPS and too few case studies with functional solutions. To increase evidence a modern prototype of a Bioseco BPS, composed of 32 cameras (stereovision) with onboard AI was validated on a Vestas V150 turbine in Germany in 2022. The ultimate goal was to validate the BPS' performance against currently best-known test criteria from the German KNE competence center. The BPS scans the airspace 360° around a wind turbine and switches it off in case of a bird of a defined size enters the danger radius. The validation of the parameters detection rate, classification rate, reaction time and localization uncertainty took place on 50 days between March and September. Flight paths and the bird species were determined using laser rangefinders. These reference objects were compared temporally and spatially with the BPS data to determine a detection rate. The size classification of the BPS was checked simultaneously. GPS data from different bird-like drones, which flew around the turbine were used to calculate the localization uncertainty. To test reaction time the signal transmission delays caused by BPS and turbine control system were determined. The BPS can detect and classify the size and localize different birds in the vicinity of the wind turbine, independent of the number of objects tracked simultaneously. The detection range depends on the birds' size. Larger birds like the white-tailed eagle, white stork, and red kites are detected within a range of up to 700 meters with an efficiency of 90 % (based on > 1000 measurements). The BPS correctly classified the size of red kites in 94 % of all cases. The positioning error is <10 % in the range of 500 meters and <20 % in the range of 800 meters. The reaction time is compensable and mostly influenced by the turbine controller, while BPS signal delay is often close to 0 s. Our results show the BPS high capability to reduce bird collision risks and that it meets industry expectations, e.g. KNE requirements in Germany in terms of reaction time, detection rate, localization uncertainty and size classification accuracy.

Key words: Bird, detection, wind turbine, automated control, case study

AUTOMATIC DETECTION OF 3D BAT FLIGHTPATHS WITH A THERMAL CAMERA SYSTEM FOR WIND TURBINES

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The most widely used method for detecting bats around wind turbines are acoustic detectors. They provide a meaningful statistical measure for quantifying bat activity but do not help for a qualitative analysis of the bat behavior, because they do not provide flightpath information. In addition, they are very limited in range, which becomes more important with the turbine blades extending in length. That is why some bat researchers suggest the use of thermal cameras. A system for the 3D flightpath detection must consist of at least two cameras and requires a 3D calibration. That can be achieved by a calibration object with known real-world coordinates and which can be seen from both cameras at the same time. This object must be of approximately the same order of magnitude as the volume to be calibrated, which is especially challenging for wind turbine sites and thermal cameras, because a large warm object is needed. Established calibration objects include a thermal checkerboard pattern or a wand. They work well for smaller scales but produce significant errors when used on the scale of wind turbines. In this work we developed a software tool for the easy, precise and verifiable calibration of a thermal 3D camera system by using the GPS drone flight path as the calibration object. By using this approach, it is possible to do a 3D calibration of a mobile camera setup within a few minutes. After calibration, bat flightpaths can be automatically detected by the software. The flightpaths are directly given in GPS and as metric coordinates which significantly simplifies the localization relative to the turbine and the calculation of flight speed, height and celestial direction of the bats. We did 12 calibration flights in distances between 40 and 260 meters of the camera system and derived accuracies between 1 and 4 meters on average. We installed the system in the dusk hours of four June nights on a wind turbine in Germany and derived about 40 resulting flight paths. It is planned to use the system for the permanent recording on another test site in Germany in the summer of 2023. The system can also be used on offshore wind parks if the cameras can be mounted on fixed structures in a reasonable distance.
Key words: 3D calibration, thermal cameras, bat, 3D flightpath detection

FRAMEWORKS FOR EFFECTIVE WIND-WILDLIFE MONITORING REQUIRE HIGH RESOLUTION DATA FROM INTEGRATED TECHNOLOGY FUSIONS

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As wind energy expands, mitigating impacts on wildlife remains a priority. To effectively mitigate impacts, we must prioritize a robust wind-wildlife monitoring framework capable of informing management decisions that lead to no net loss to biodiversity. Such a framework is an iterative process whereby direct observations on collision and displacement effects inform mitigation techniques and subsequently are used to validate the performance of those techniques. The actual implementation of this type of framework has thus far been hindered by a lack of appropriate data. The type of accurate, high-resolution data required exceeds the capacity of most current monitoring approaches (human observers or monitoring technologies applies in isolation). Current applications of monitoring technologies struggle to harness their full potential by failing to capitalize on opportunities for integration with additional technologies and/or by a limited scope of temporal and spatial inquiry. At the emergence of this new frontier of wildlife monitoring, we demonstrate how a framework of wind-wildlife monitoring requires sensor fusion principles to facilitate the most effective implementation and integration of multiple monitoring technologies. In addition, we present several examples illustrating how sensor fusion solutions can generate high resolution data on collision and displacement effects on terrestrial wildlife across complex spatial and temporal scales.

Key words: Monitoring, Mitigation, Minimization, Technology

RECOMMENDATIONS FOR TECHNOLOGY RESEARCH AND DEVELOPMENT (R&D) FOR SCIENTIFICALLY ROBUST MONITORING OF BIRDS AND MARINE MAMMALS IN RELATION TO OFFSHORE WIND ENERGY DEVELOPMENT

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It can be difficult to study the effects of offshore wind energy development on wildlife in a statistically robust way that meaningfully informs mitigation and adaptive management. Current monitoring technologies are often limited in their ability to collect the necessary types and amount of data required, and furthermore are seldom well-integrated into offshore wind infrastructure and operational procedures, which can limit their effectiveness and increase costs. The U.S. National Offshore Wind Research & Development (R&D) Consortium funded an assessment of current bird and marine mammal monitoring technologies' ability to 1) answer priority research/monitoring questions, 2) produce statistically robust data to inform meaningful adaptive management, and 3) integrate into normal equipment and operations for fixed and floating offshore wind energy development. This assessment was built, in part, from existing databases of monitoring technologies, as well as a series of workshops in 2022-2023 with experts in bird and marine mammal research, wildlife monitoring technologies, and offshore wind energy. Expert stakeholders identified a variety of research and development opportunities to deploy technologies on different platforms, improve remote data access, and standardize the external resources needed by wildlife monitoring technologies (e.g., power, data transfer, physical space, etc.). Experts indicated that capacity designated for wildlife monitoring systems in turbine designs would greatly facilitate the ability of offshore wind developers to meet environmental monitoring requirements, which are typically finalized later in the development process than other aspects of wind farm design. It was also suggested that the development of clear government requirements for data sharing protocols, standards, or platforms could help to drive collaboration and innovation. Recommended R&D for tags and other animal-borne sensors focused on increasing sensor reliability and accuracy, further miniaturization of tags and improved battery life relative to tag size, improved attachment methods, and increasing remote download capabilities. More generally, experts noted the potential value of integrating a range of monitoring technologies that provide data of differing types or at complementary scales. Ultimately, a combination of focused R&D, cross-sector coordination and streamlining, and acceleration of development and testing timelines were recommended to improve monitoring technologies. Continued discussions among multidisciplinary teams of offshore wind energy engineers, technology developers, wildlife biologists, regulators, operations and maintenance specialists, and other experts will be needed to ensure that wildlife monitoring technologies are developed that 1) better meet conservation and regulatory needs, and 2) can be more safely and effectively integrated into OSW development and operations.

Key words: technology, monitoring, research and development, birds, marine mammals

REAL-TIME PASSIVE ACOUSTIC MONITORING FOR AGGREGATIONS OF SPAWNING COD AT AN OFFSHORE WIND FARM

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South Fork Wind is a 12-turbine offshore wind project on the east coast of the United States that is being developed by Orsted and Eversource. This wind farm is located in an area with complex benthic habitats including known spawning habitat for Atlantic cod (Gadus morhua). Atlantic cod form spawning aggregations throughout their geographic range, and male cod exhibit a complex set of spawning and courtship behaviors that includes vocalizations (low frequency grunts). These vocalizations can be detected using Passive Acoustic Monitoring to identify where and when spawning activity is occurring. Following consultation with regulators, the project received a permit condition to perform monitoring and adaptive management during the cod spawning season. Orsted partnered with researchers at Rutgers University and JASCO Applied Sciences to develop a near real-time monitoring solution for Atlantic cod. The objective of the monitoring was to determine the presence/absence of spawning cod within the South Fork Wind lease area and to use collected data to determine if an adaptive management strategy would need to be implemented during site preparation works. A Slocum glider equipped with a JASCO OceanObserver PAM system and oceanographic sensors was used to monitor for cod spawning activity within the wind farm area. The glider can cover a distance of approximately 20km per day, and the glider was programmed to perform alternating east-west and north-south transects throughout the wind farm. The OceanObserver system onboard the glider processed the PAM data continuously using an automated grunt detector to quickly analyze incoming data and evaluate whether any candidate cod grunts were detected. These data were transmitted as frequency contour messages to the acoustic analysts ashore who reviewed and verified them as cod grunts. The glider team prepared daily summary reports for Orsted which included a map of the glider tracks from the previous day and the number and location of verified cod grunts that were detected. The glider monitored the South Fork Wind area for 23 days, during which time it detected four cod vocalizations. The glider was able to maintain its' position with the wind farm, despite the strong currents and storm activity observed during the monitoring period. The monitoring hardware performed reliably, and near real-time data transmission was maintained throughout the monitoring period. This case study demonstrates how offshore wind developers can leverage advanced technologies to mitigate impacts to natural resources and perform adaptive management when necessary.

Key words: Passive Acoustic Monitoring, Atlantic cod, real-time, adaptive management

PILOTING AND VALIDATING MONITORING TECHNOLOGIES FOR PELAGIC FISH BIOMASS AND BIODIVERSITY IN FLOATING OFFSHORE WIND FARMS

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There are still uncertainties regarding the potential environmental impact from a floating offshore wind farm (FOWF) due to the floating technology being a relative novel development solution. Studies in FOWFs will hence improve the knowledge base. Using the world's first FOWF, Hywind Scotland (30 MW), as area for piloting of monitoring technologies for pelagic fish biomass and biodiversity, the wind farm operator Equinor and research collaborators have gained new knowledge on the potential and possibilities for glider and environmental DNA (eDNA) technologies for future mapping and monitoring in remote dynamic offshore areas. For FOWFs, where the turbines, cables and mooring lines will create limitations for conventional monitoring activities like trawling, novel monitoring technologies are needed. The glider study, utilizing a small autonomous vehicle (Sailbuoy), collected 28 days of high-quality data during the campaign in the FOWF during summer 2021. The Sailbuoy was equipped with an echo sounder, and some additional sensors. The study revealed that plankton and fish stock biomass showed a "peak" during the sampling period. The "peak" was strongest in the area closest to the FOWF. This might be due to increased turbulence around structures, which increase water mixing and circulation of nutrients. Hence, the structures might contribute to a boost of the natural bloom, i.e. temporal movement and attraction. Results from the eDNA pilot study in 2021 indicated that there were more sprat and Atlantic herring in the FOWF area compared to the reference area. This difference of relative abundance at the time of sampling indicates the suitability of the technology. Water samples were taken from two depths (10 and 50 meters), and the results also revealed that demersal fish species showed stronger signals in samples from 50 meters. Results obtained are promising for the technology, showing its potential for distinguishing species abundance in different areas and depths. In May 2023, follow-up studies with Sailbuoy and eDNA technologies will be performed in the present world largest FOWF, Hywind Tampen (88 MW), on the Norwegian Continental Shelf. The Sailbuoy campaign will include one extra buoy for control transects and investigate confounding factors like depth and currents. The eDNA study will include sampling at different times upstream and downstream, in addition to inside the FOWF, to learn more about the transport of DNA with currents, although both lifetime of DNA and dilution of DNA need to be considered in interpretation of results.

Key words: wind farm, monitoring, fish, eDNA, autonomous vehicle

UTILIZING DATA FROM AUTOMATED CAMERA-BASED MONITORING SYSTEMS TO QUANTIFY FLIGHT BEHAVIOR AND ASSESS SPECIES-SPECIFIC COLLISION RISK OF BIRDS WITH WIND TURBINES

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The increasing number of wind energy sites developed globally has consequently resulted in a green-on-green predicament, due to an increase in avian mortality caused by collisions with wind turbines. The proportion of collision-related fatalities is not evenly distributed across species, indicating that some species groups are more prone to turbine collision. Such differences between species have been proposed to be affiliated with species-specific foraging and flight behavior. Some wind farms have implemented automated camera-based monitoring systems, e.g., IdentiFlight to mitigate the impact of wind turbines on protected birds. These systems have promoted the collection of large amounts of unique data that can be used to describe flight behavior in a novel way. The aim of this study was to evaluate how this unique data can be used to create a robust quantitative behavioral analysis, which can be used to identify risk-prone flight behavior. The study also sought to investigate how the flight behavioral traits; head position, active flight, track symmetry, and track tortuosity can be used to model collision risk along with other influencing factors i.e., weather variables (temperature, wind speed, and cloud coverage) and temporal variables (time of day and time of year). This was achieved through a case study at a wind farm on the Swedish island of Gotland in which the behavior of birds from eleven different genera was studied. The flight behavior of these species was assessed using data collected by the IdentiFlight system, e.g., flight trajectories and images of the birds throughout their flight track. The results demonstrate how data from camera-based monitoring systems can be utilized to quantitatively describe flight behavioral traits and identify risk-prone flight behaviors, e.g., tortuous flight and foraging behavior. Moreover, the results confirm the species-specificity of the four flight behaviors and indicated that all four traits can be used to predict collision risk along with species as a categorical factor. The framework provided in this study along with the results of the case study can be used to identify risk-prone species based on phylogenetic relatedness and flight behavior.

Key words: collision risk, IdentiFlight, wind turbine curtailment, flight behavior

USING ACOUSTICS AND THERMAL IMAGING TO ASSESS BAT BEHAVIOR AND ACTIVITY AT TOWERS

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Wind energy production has dramatically increased but not without unintended environmental impacts, such as high bat mortality rates. Current pre-construction mitigation strategies acoustically monitor bat activity at planned wind energy facilities to predict mortality and improve siting. However, there is high variation between pre-construction models and post-construction fatalities, which could suggest either attraction of bats to wind turbines or high variability in acoustic monitoring methods. Thus, we supplemented acoustic monitoring with thermal cameras to monitor bats at two sites (~80 km apart) being surveyed for wind energy development at meteorological evaluation towers (MET) in southern Texas, USA. Using AXIS Q1942-E cameras, we recorded nightly bat activity in parallel with Song Meter 4 BAT-FS acoustic detectors. We used Kaleidoscope Pro 5 to identify bat species in acoustic recordings and machine learning in Python 3.8.5 to distinguish bats from other thermal sources in video recordings. We analyzed detection counts produced from both methods using generalized linear models with atmospheric conditions as covariates. We detected 15 bat species at Tower 1 and 9 bat species at Tower 2 with acoustic monitoring. The most frequently detected species at both towers was Tadarida brasiliensis. We observed peak T. brasiliensis activity in April 2021 at Tower 1 and May 2021 at Tower 2. The second most frequently detected species was Lasiurus cinereus. We observed peak activity of L. cinereus during April 2021 at Tower 1 and May 2021 at Tower 2. Lasionycteris noctivagans was the third most detected species at Tower 1 with peak activity in April 2021 and Lasiurus intermedius at Tower 2 with peak activity in June 2021. Absolute humidity and lunar illumination positively affected detections with both acoustic recorders and thermal cameras whereas temperature positively affected acoustic detections only. Thermal imaging detections peaked in the middle of the night whereas acoustic activity was bimodal with lower detections during the middle of the night. Additionally, we observed behavioral patterns including increased focus on specific points on the tower that changed during consecutive nights with wind direction and when more than one bat was in a thermal camera frame. These behaviors may suggest olfactory interactions with the MET and potential new hypotheses regarding bat attraction to wind turbines. We recommend implementing thermal imaging into future acoustic surveys to further examine bat activity and behavior in different ecosystems.
Key words: activity, bats, behavior, monitoring, towers

RADAR BASED METHODS TO STUDY BIRDS MOVEMENT PATTERN IN ONSHORE WIND FARMS OF CHINA

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The emerging market of wind power has intensified the conflicts between wind turbines and waterfowls in costal area of China. Despite macro-scale of birds migration have been studied, birds movement pattern and flying behavior in and around wind farm is lack of knowledge in China. In this study, we used radar detection combined with field observation methods to assess birds seasonal movement pattern, flying corridor and habitat distribution in and around a coastal wind farm. We used radar to measure birds position, heading, flying height, flight speed and flying route, analyzed daily and nocturnal movement pattern and compared movement pattern in spring and autumn. We also tracked birds flying route and flying height at the turbine site to assess whether birds would automatically avoid the turbine. As radar is not able to identify species, we carried out field survey to observe different species flying behaviors across the wind farms and compared with radar data to find out birds foraging habitats. Overall, the preliminary result of this study revealed there existed a migratory corridor along the costal line across the wind farm. Over half of the migration peak occurred over night, lasting 6 to 8 hours till the day after, and the nocturnal migratory birds heading north and northwest in spring, and heading southeast in autumn. Over 70 percent of birds flew below 200 meters at rotor swept space. Results also showed that egrets fly at the rotor-swept zone of turbine and showed avoidance behavior at the range of 10 m from the turbine; flocks of shore birds would rise height when passing across turbine. Comparing with radar tracking data, we testified the foraging habitat of migratory and local waterfowls. The study provided statistic proof of birds migration, including birds flying pattern, migratory corridor, migration peak time and potential risk analysis for wind farms and local administrations to reassess the wind farm impact on migratory birds. A warning system of migration based on radar data was also provided for the wind farm. As birds migration is influenced by many factors, such as meteorologic factor, and migration intensity may also vary over years, further research needs to be carried out in the future.

Key words: birds movement,radar, migration

RESULTS FROM TESTING - A MULTI-SENSOR APPROACH FOR MEASURING BIRD AND BAT COLLISIONS WITH WIND TURBINES

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Offshore wind energy development is regionally well-established. It is poised for rapid growth and expansion worldwide to meet carbon-free energy targets. Understanding the potential magnitude of bird and bat collisions at offshore wind farms is an important consideration for regulators and operators. Standardized carcass searches are impossible, and estimation unvalidated. Automated collision monitoring technologies may help focus mitigation where needed to advance offshore wind energy. Collision monitoring systems can also identify the specific time and blade location of strikes, which is necessary to advance minimization strategies to reduce wind farm fatalities. Western EcoSystems Technology, Inc. (WEST) leads a collaboration with the Netherlands Organisation for Applied Scientific Research (TNO) and the National Renewable Energy Laboratory (NREL) to advance the testing of an automated, multi-sensor system for detecting and quantifying bird and bat collisions at offshore wind turbines. It is funded primarily by the US Department of Energy's, Wind Energy Technologies Office. The primary objective of the project is to advance the WT-Bird® system to detect large, medium, and small bird and bat collisions during day and nighttime hours. Three major technological advancements from the project are to: 1) improve the sensitivity of acceleration sensors to detect collisions of small birds and bats, 2) integrate machine learning (ML) algorithms to process imagery data collected by the cameras, and 3) create a launching system and projectiles of multiple sizes to realistically simulate collisions. The updated system is designed to detect collisions including objects as small as 8 grams using non-metallic sensors installed inside of the turbine blades. Independently operating cameras installed at the base of the turbine document bird and bat presence near the camera, and document collision events. The system was tested at a single turbine at NREL's campus using the projectile launching system. It had a greater than 70% detection rate across all size classes. Subsequently, the system was installed on the University of Minnesota turbine where it was operational during 2022 and 2023, and validated with independent ground-based fatality searches. The WEST ML system provides edge-AI processing of camera imagery at the turbine, identifying presence of birds and bats within the camera view. The estimate from the WTBird® detections (18.46 fatalities) was within the 90% confidence interval of the ground-based estimate (16.88) with a difference in the point estimates of only 1.58 fatalities. System improvements will be highlighted. Validating the system at an offshore wind farm will commence in 2024.

Key words: Technology, Machine Learning, Mitigation, Measuring Collision, Validation Trial

PROBABILISTIC METHODS – WILL THEY MAKE PERMISSION PROCESSES EASIER AND FASTER?

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Goal
In light of difficult legal aspects regarding the permission of onshore wind energy projects in Germany, the goal was to develop and implement a mathematical method / collision risk model (CRM) to objectively assess and quantify the impact of wind energy projects on bird species which are sensitive to collision risks.

Material
Previous CRM include the dimensions of the wind mills / farm, features of birds flight behaviour and – on land – distance to individual nest sites to calculate an individual collision risk. Important features of the flight behaviour, namely flight altitude, habitat use and avoidance of wind farms, typically rely on very sparse empirical results provoking high uncertainties while the magnitude of avoidance exerts a very high impact on the calculated collision risk. We collected flight behaviour data for a number collision-sensitive bird species such as Red Kite, White-tailed Eagle and White Stork stemming from German and European wide telemetry projects. We also collected habitat data (CORINE land cover) and exact locations of some 12,000 wind turbines in Germany. For Red Kite the dataset turned out to be large enough (www.life-eurokite.eu) to yield reasonable and representative results.

Results
We developed a new CRM ("hybrid model") by combining a 3D habitat-use prediction of birds with a mechanistic description of bird strike (the latter related to the "Band-model"). The model estimates the local and individual collision risk (given a specific wind turbine and nesting-scenario) including the calculation of the associated uncertainties. This model combines empirically well-grounded characteristics of flight behaviour, habitat selection, wind mill and distance to nest sites. It also includes new insights with respect to the avoidance behaviour on different spatial scales. Model predictions are qualitatively and quantitatively validated based on various theoretical and empirical studies and data, including those which intensely monitored bird flight and collision victims in large empirical studies. The new model provides a promising tool to quantify the WEA-related collision risk under specific local condition of WEA-construction, where estimates are empirically well grounded and validated. Further improvements of the model will be mentioned.

Conclusion

The Hybrid-Collision Risk Model is able to provide a fast approach to calculating individual collision risk for wind energy projects. It will also enable us to assess collision risks / impacts on a regional / national scale for further wind (or renewable) energy projects reconciling issues of the biodiversity crisis and climate change.

Key words: collision risk models, probabilistic methods, additional mortality, flight behaviour

GUIDANCE FOR PRE- AND POST-CONSTRUCTION MONITORING TO DETECT CHANGES IN MARINE BIRD DISTRIBUTIONS AND HABITAT USE RELATED TO OFFSHORE WIND DEVELOPMENT IN THE UNITED STATES

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Offshore wind (OSW) development is rapidly increasing in the U.S. Atlantic, bringing with it a range of potential effects to bird populations that use the marine environment for foraging, roosting, small- and large-scale movements, and other activities. To ensure site-specific research is well-designed to answer research questions and reduce uncertainty surrounding potential OSW effects to marine birds, subject matter experts (under the auspices of the Offshore Wind Environmental Technical Working Group) have developed guidance for conducting studies of macro- to meso-scale changes in avian distributions and habitat use at OSW facilities in the U.S. This expert workgroup includes experts from Canada, the U.S., and the UK, and is led by representatives of U.S. federal regulatory agencies. This effort is intended to ensure consistency in monitoring across OSW projects, improve efficiency and thus reduce the overall cost of monitoring to the industry, ensure the generation of meaningful results, and facilitate the use of site-level data to better understand potential cumulative effects of displacement. The guidance document was developed via a combination of review of existing guidance, literature review of existing studies from Europe, power analyses, and expert elicitation. It identifies key research questions regarding displacement, attraction, and macro-to meso-scale avoidance, and provides an overall process for the selection of research questions, focal taxa, and data collection methods. This includes guidance on the strengths and limitations of various study methods, and on designing studies to ensure adequate statistical power to detect effects. The guidance also includes specific recommendations for study design and data collection using observational surveys (e.g., digital aerial and boat-based surveys), including recommendations on the use of Before-After Gradient (BAG) designs, study area size, percent coverage of the study area during surveys, specific field and analytical methods, and other considerations. Finally, the effort includes recommendations on data consistency and transparency to ensure that the results of site-specific pre- and post-construction monitoring studies are available to inform meta-analyses, cumulative impact assessments, and other large-scale assessments of OSW effects to marine bird populations. The recommendations derived from this effort are intended to be used by government and regulatory agencies, offshore wind developers and their consultants, and other stakeholders in the U.S. and elsewhere around the globe to improve the quality of site-specific research and monitoring efforts, and improve our understanding of displacement, attraction, and avoidance effects to marine birds from OSW energy development.

Key words: Research, Marine Birds, Displacement, Avoidance, Attraction

TWENTY YEARS OF WOLF MONITORING PLANS AND EIA IN PORTUGAL: CAN WE DO IT BETTER?

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The continuous rise of human population globally results in a heavy use of landscapes and natural resources. New human infrastructures, like transportation or energy facilities, are a particular risk to large carnivores, especially if they are built within their ecological strongholds. Environmental Impact Assessments (EIA) are the most widespread planning and management tools, ensuring that a comprehensive evaluation is undertaken anytime a new development is projected, leading decision-makers to well-informed choices. In Portugal, with an estimated population size of around 300 individuals, wolves are an endangered species with full legal protection. They occupy mountainous areas, where there has been a big overlap with wind energy development for the last 20 years. Consequently, dozens of wolf monitoring plans under EIA procedures were established to evaluate population status and specify adequate mitigation or compensation measures. Here, we reviewed the 30 most important monitoring programs undertaken nationwide to answer four key questions: 1) do wolf programs examine the adequate biological parameters to reach objectives? 2) are the study design and resulting data sufficient for measuring impact? 3) does statistical analysis of the data lead to robust conclusions? and 4) do the assessments achieve stated objectives? Overall, we found a mismatch between the stated aim of wolf monitoring and actual results reported, and it is often the case that neither aligns with national wolf monitoring guidelines. Despite the vast field effort and methodologies employed, data analysis makes almost exclusive use of relative indexes or absolute survey numbers, with little to no consideration for the (imperfect) observational process. Adding to this, around 50% of all the monitoring plans makes no use of any statistical inference to evaluate data. This makes comparisons across space and time difficult and inconsequential. We suggest the development of standardized monitoring protocols and advocate for the use of statistical methods that account for imperfect detection on the observational process to guarantee accuracy and reproducibility, like spatial capture-recapture and derivative models. Impact assessments make use of time-series of ecological state variables to infer cause-consequence relationships with the development of some infrastructure. We need to step forward in data analysis and make use of robust and meaningful estimates to drive sound conclusions, so that EIA measures can really contribute to this large carnivore conservation.
Key words: Review, wolf, monitoring plans, environmental assessments, observational process

SIX YEARS OF USING THE GUIDELINES FOR ASSESSMENT OF WIND FARMS IMPACT ON LARGE CARNIVORES IN CROATIA

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In 2016 this team of authors compiled the “Manual for assessment of wind farms impact on large carnivores”. Since then the manual is posted at the web pages of the Croatian Ministry of Economy and Sustainable Development (and it’s State Institute for Nature protection) http://www.haop.hr/hr/publikacije/strucni-prirucnik-za-procjenu-utjecaja-zahvata-na-velike-zvijeri-pojedinacno-te-u. Practically all Environmental Impact Assessment studies on wind farms preformed in the meantime followed these guidelines. The Guidelines propose an assessment methodology based on the sensitivity maps (probabilistic grids), using previously collected radio telemetry data on large carnivore occurrences relative to habitat characteristics. The sensitivity maps indicated the importance of certain area for each species of large carnivores through defined nine classes at the resolution of 250x250 m. The main field method comprises one year of monitoring of all signs of presence of large carnivores (brown near, wolf and lynx) including the grid of automatic cameras and occasionally radio telemetry tracking. Habitat loss was calculated as a circle with radius of one km around each wind turbine for general carnivore needs and as two km circle, when the impacts on their reproduction areas had to be assessed. The threshold (in %) of further loss for each class of habitat was set, also with calculated absolute limits (in square kilometres) for the entire area of large carnivores permanent and occasional occurrence in Croatia. The calculated values cannot exceed cumulative threshold on the national level. The acceptable future loss of habitat was set at maximum of 1% for the class 9 habitat and more in less good classes. Since the major threat to large carnivore survival is habitat fragmentation and habitat loss, the strategy for reduction and avoidance of individual and cumulative impacts was developed. After six years of experience we are challenging the sizes of circles around the denning (reproduction) sites (2 km) and the correctness of cumulative effect calculations. More data from the post construction monitoring are needed. We also urge the spatial planers and local municipalities not to propose the development of additional wind parks in mountainous habitats of large carnivores. The new edition of Guidelines is perceived in the near future using the increased number of freshly obtained telemetry locations of large carnivores and the updated maps on vegetation cover, as well as on new man-made structures.
Key words: Large carnivores, Croatia, guidelines, assessment, uncertainties

REFERENCE VALUES OF BAT ACTIVITY FOR THE POTENTIAL IMPACT ASSESSMENT OF RENEWABLE ENERGIES

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Wind power facilities will be strongly increased in the coming years in Spain and many other countries due to recent changes in national energy policies, which promote a much needed transition to renewable energies. Bats and birds are among the fauna that can potentially be adversely affected by wind turbines. Wind turbines can cause mortality of bat populations by direct collision and barotrauma. Most impact assessment protocols for the bat communities include the recording of bat acoustic activity in the vicinity of the projected facilities. Nonetheless the decision makers often lack objective criteria to determine critical thresholds of activity, and hence it is hard to establish when corrective measures or even reallocations of the planned facilities are needed or desirable. The roughly 1000 existing and planned wind turbines currently deployed in Catalonia (NE Spain) are placed mostly below 900 m.a.s.l within the Mediterranean biogeographic domain. They are mostly surrounded by 8 different habitats (in decreasing order): shrublands, annual cultures and meadows, Aleppo pine, cork oak, holm oak, black pine and riparian forests, and wetlands. In the study region there is a network of acoustic monitoring stations called ChiroHabitats, designed to obtain trends on bat populations. The network accounts for 115 sampling points in the habitats and altitudinal ranges affected by the wind development plan. Between 2020 and 2022, during the months of May to October, bat activity was recorded during 30 min before sunset to 30 min after sunrise. We analyzed the acoustic contacts in the sampling locations. We considered an acoustic contact (bat pass) when in a 5 second sound file it has minimum two distinguishable echolocation calls. Hourly bat activity values for each sampled habitat have been determined, both at community and phonic group level, providing the median activity and the first and third quartile as a quick evaluation tool. This data has been provided to the environmental authorities and are currently used as a support tool in the impact assessment. We suggest that such activity thresholds should be made available to those biogeographic regions where wind farms are being implemented, to better predict their potential impact on bat populations.
Key words: wind impact, bats, reference values, bat activity

A GLOBAL FRAMEWORK FOR ESTABLISHING BAT FATALITY THRESHOLDS AT WIND ENERGY FACILITIES

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Bat fatalities from wind turbine blades is a global phenomenon, but the impact to bat populations varies by species and location. Ensuring that wind energy generation does not cause biodiversity loss is a global conservation priority, but must be applied at each facility for each bat species of interest. The goal of this work is to ensure that global expansion of wind energy development does not lead to significant population-level declines of bat species. We provide a decision framework for when and how mitigation is applied under adaptive management. The framework balances responsibility among conservation and industry stakeholders and transfers the burden of defining acceptable risk and mortality to the conservation community. Industry is then responsible for incorporating risk in planning phases and implementing conservation measures. Government and financial lenders are responsible for ensuring that thresholds (and the level of mitigation actions required to meet these thresholds) are included in environmental permits, loan documents or other instruments, and that monitoring occurs to demonstrate that these thresholds/actions are being implemented. The framework starts with a proactive approach when risk is assessed, and initial risk avoidance measures or operational constraints are established. This process should occur early in the project planning so risk avoidance can be accounted for in project and financial projections and planning. The second phase uses adaptive management that responds to the observed mortality relative to a facility threshold by relaxing or increasing risk avoidance measures. Thresholds are based on species conservation status, the population size in the project area, and species' annual growth rate. For bats classified as Critically Endangered or Endangered by the IUCN or a regional or national assessment, the project threshold is set at <1 fatality per facility (i.e. no acceptable level of fatalities) on a rolling three-year average. For less imperiled species, we accept some level of risk and impact. We propose a threshold-setting method that theoretically sustains a stable population size. Setting this threshold requires knowledge of the regional or local bat population size, the size of the project area of influence, and population growth rate. The framework is flexible to allow for new information to be included as it becomes available and to incorporate currently known information when possible. We adopt a proactive, conservative approach that encourages the scientific and wind industry stakeholders to work together to promote sustainable bat populations in the face of climate change.

Key words: adaptive management, bats, decision-making, fatality minimization, thresholds

ESTIMATION OF FLIGHT INTENSITY OF THE SWIFT APUS APUS DURING MIGRATION OVER THE BALTIC SEA USING THE DISTANCE METHOD, BASED ON VISUAL OBSERVATIONS AND DATA OBTAINED BY PARAMETRIC CLASSIFICATION

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When assessing the impact of planned offshore wind farms in the Baltic Sea, located between Sweden and Poland, on the population of migratory bird species, it is important to collect accurate baseline data on the abundance of migratory birds over the study area. This is essential, in order to determine what proportion of a species' population will be affected by an offshore wind farm. Currently, field studies use survey methods supported by the use of ornithological radar recording overflights from research vessels. Ornithologists observe and record all migrating birds crossing the research transect - transect observations. Some species, such as the swift Apus apus, due to their build and body size, are difficult for the observer to see against the sky or sea and at greater distances than 300 meters. Situations arise where the observer does not see these birds or does not observe all individuals in flocks that are detected by ornithological radar. Ultimately, in the analyses, there is an underestimation of the number of recorded individuals migrating over the studied area and, in effect, the preparation of a less accurate estimate of the number of swifts flying over wind farm areas. This may be reflected in further analyses performed in the process of environmental impact assessment, for example, when calculating the risk of bird collisions and relating these losses to the total migrating population of the species. To improve the accuracy of swift abundance estimation using the traditional method, parametric classification of data collected by ornithological radar was performed. The first stage of classification consisted of selecting additional flight routes of swifts from flocks recorded by the ornithological radar, which were not confirmed by the observer during the field survey. The second stage consisted of selecting additional flight routes on the basis of flight characteristics, i.e. flight trajectory, speed, distance between flight routes, characteristic flight formation for the species. As a result, a higher number of migrating swifts was found over the study area than during the first stage and in the visual observation modules on transects. Using data from the first stage of distance-based classification resulted in 2.5 to 2.9 times higher flight intensities, and the second stage of parametric classification yielded 5.9 to 6.4 times higher flight intensities compared to calculations based on observation transects. The results of this modelling will affect a more accurate estimation of the impact of offshore wind farms on migrating swifts.

Key words: swift, ornithological radar, migration, offshore

DETERMINING BAT ACTIVITY AT TWO WIND FARM SITES IN TUNISIA

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Wind energy production is rapidly expanding in developing economies, often into data deficient areas where the uncertainty of bat activity increases the risk to the feasibility of wind energy development. Wind farms have a negative impact on bats primarily due to fatalities resulting from collisions or barotrauma which is aggravated by project development on migratory pathways or close to important roosts. Baseline data of bat activity is usually collected manually at ground level at discrete surveys over short periods of time often mischaracterizing the height profile of bat activity and species composition. In this paper we aim to determine bat activity at two wind farms sites in Tunisia using continuous automatic bat recordings over multiple months at different heights above ground and compared the results against traditional manual discrete surveys at ground level. We use data collected over a period of 16 months (from 2019 to 2020) at El Ktef wind farm in the Solb ech-Charki peninsula and data collected over a period of 12 months (from 2020 to 2021) at Sidi Daoud wind farm near Cap Bon. We found average bat activity levels of 2.06 contacts/night at 9.5 meters and 0.01 at 67 meters at the El Ktef site (n=430), and 3.48 contacts/night at 27 meters and 1.12 at 75 meters at the Sidi Daoud site (n=500). The results show a non linear trend in bat activity over height above ground with a peak at the height of the lower section of the rotor swept volume. The species composition is also markedly different at lower heights. The results suggest that the lower section of the rotor swept volume may be of higher collision risk for bats as this section is where the time duration of the blade at tip speed is longest. In this paper we discuss the implications of these results in bat fatalities risk modelling and make recommendations for surveys in data deficient sites. We further discuss the current trend in wind turbine characteristics and how it relates to impact on bats.

Key words: Bat activity, Wind turbine, Risk assessment, Tunisia

FLIGHT HEIGHTS OBTAINED FROM GPS VERSUS ALTIMETERS INFLUENCE ESTIMATES OF COLLISION RISK WITH OFFSHORE WIND TURBINES IN LESSER BLACK-BACKED GULLS LARUS FUSCUS

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The risk posed by offshore wind farms to seabirds through collisions with turbine blades is greatly influenced by species-specific flight behaviour. Bird-borne telemetry devices may provide improved measurement of aspects of bird movement, notably individual and behaviour specific flight heights. However, use of data from devices that use the GPS or barometric altimeters in the gathering of flight height data is nevertheless constrained by a current lack of understanding of the error and calibration of these methods. Uncertainty remains regarding the degree to which errors associated with these methods can affect observed flight heights, which may in turn have a significant influence on estimates of collision risk produced by Collision Risk Models (CRMs), which incorporate flight height distribution as an input. Using GPS/barometric altimeter tagged Lesser Black-backed Gulls Larus fuscus from two breeding colonies in the UK, we examine comparative flight heights produced by these devices, and their associated errors. In this talk we present a novel method of calibrating barometric altimeters using behaviour characterised from GPS data and open-source modelled atmospheric pressure. We examined the magnitude of difference between the derived GPS and altimeter offshore flight heights, comparing these measurements across sampling schedules, colonies, and years. We found flight heights derived from altimeter data to be significantly, although not consistently, higher than those produced from GPS data. This relationship was sustained across differing sampling schedules of five minutes and of 10 seconds, and between study colonies. We found the magnitude of difference between GPS and altimeter derived flight heights to also vary between individuals, potentially related to the robustness of calibration factors used. Collision estimates for theoretical wind farms were consequently significantly higher when using flight height distributions derived from barometric altimeters. Improving confidence in telemetry-obtained flight height distributions, which may then be applied to CRMs, requires sources of errors in these measurements to be identified. Our study improves understanding of the calibration processes required for flight height measurements based on telemetry data, with the aim of increasing confidence in their use in future assessments of collision risk and reducing the uncertainty in predicted mortality associated with wind farms.

Key words: Collision risk assessment, Marine Renewable Energy, Seabirds, Telemetry calibration

FLIGHT BEHAVIORS IN SUBTROPICAL SEABIRDS EXACERBATE COLLISION RISK FOR WIND ENERGY DEVELOPMENT IN DEEP-WATER ENVIRONMENTS

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GOAL. Collision mortality and injury are among possible adverse impacts to marine birds at offshore wind farms. Evaluating collision risk requires comparing flight height to rotor swept zones (RSZs) of generator turbine blades. Flight height is difficult to estimate in deep oceans where fixed, remotely-operated instrumentation cannot be deployed. We use flight heights estimated from vessel-based observations of seabirds to investigate potential for taxa- or behavior-specific patterns in exposure to the RSZ. We also discuss how vessel-based observations complement other approaches to estimating flight heights and augment the range of conditions in which seabird flight heights can be characterized. MATERIAL AND METHODS. Flight heights were estimated from large vessel surveys in subtropical waters off the southeastern United States, then compared to characteristic vertical dimensions of RSZs. Data were gathered over multiple years, covered thousands of kilometers of deep-water surveys, and featured species rarely assessed for collision risk (e.g., Onychoprion fuscatus, Pterodroma hasitata, Puffinus lherminieri, and Fregata magnificens). RESULTS. Certain subtropical seabirds regularly fly 50-200 m above the sea, placing them at risk for colliding with offshore wind turbines. Switching from high search modes to low prey captures at the ocean surface suggest that foraging style might exacerbate collision risk given the repeated ascents and descents in species like Sooty Tern and Magnificent Frigatebird. Binned flight height data can be less accurate and precise than instrumented measurements (e.g., lidar, 3-d camera/radar systems). But larger sample sizes, and key meta-data such as wind speed, a major influence on flight height, can be gathered over broader environmental conditions than from fixed instruments. CONCLUSION. Vessel-estimated flight heights furnish a means to evaluate collision risks of some pelagic seabirds outside the breeding season far away from nesting colonies, limitations that also thwart satellite or geolocator tagging to assess seabird flight height. Vessel-estimated flight heights also can be used when and where fixed monitoring systems (e.g., MUSE, ATOM) cannot be deployed on floating turbines sited in deep-water wind energy areas.
Key words: Offshore wind, seabirds, collision risk, flight height

ASSESSING VULNERABILITY OF MIGRATING ANATIDAE (WATERFOWL) POPULATIONS TO OFFSHORE WIND FARMS

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Vulnerability assessments are a useful tool for identifying potential risks associated with offshore wind farms (OWFs), and have been widely applied to seabird species which spend a large portion of their annual cycle at sea. However, these assessments have yet to be conducted for species groups that only interact with the offshore environment during a short period annually. This can be an issue when legislative protections applied to these groups require that potential impacts by OWF developments must be assessed. Each year millions of Anatidae (waterfowl: geese, swans, ducks, sea ducks and sawbills) migrate across sea areas, and therefore may interact with OWFs briefly. However, a comparative assessment of their vulnerability to OWFs during these migrations, to aid OWF development consenting processes, has not previously been conducted. Here we present the results of a vulnerability assessment for this family, using those populations migrating in and out of the UK as a case study. An index of severity of interaction was calculated using metrics that were indicative of behaviour and morphology (flight manoeuvrability, flight altitude, nocturnal flight activity, and avoidance rate), and population status and demography (biogeographic population, adult survival, threat status, and Birds Directive status). These metrics were combined with a measure of exposure to OWFs for each population, in order to calculate a vulnerability index. The vulnerability index for each Anatidae population considered was then ranked. Currently, populations migrating across the North Sea are most vulnerable, as this is where the highest concentration of OWFs is found, creating a higher likelihood of exposure. In general, ducks were the least vulnerable species group, but all groups have some level of risk. The sensitivity of the vulnerability index to its constituent metrics and their uncertainty was investigated, and the results of this will be presented. Notably, the accuracy of the vulnerability index was limited by the availability of empirical data for many of the constituent metrics, particularly those indicative of behaviour and morphology. Key data and knowledge gaps are identified, and recommendations are made for which of these are the highest priority to fill in order to reduce OWF consenting uncertainties. This vulnerability assessment provides an improved understanding of how UK Anatidae migrants might be affected by OWFs on a species by species basis, and provides an assessment framework which can be extended to other migrant groups around the world that may encounter OWFs.
Key words: Migration, wildfowl, exposure, uncertainty, assessment

A COMPREHENSIVE METHODOLOGICAL APPROACH FOR QUANTIFYING POPULATION AND CUMULATIVE EFFECTS ON BIRD AND BAT SPECIES IN PRE- AND POST-CONSTRUCTION STUDIES: SOUTH BANAT REGION OF SERBIA AS A CASE STUDY

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Several large-scale WFs are already operational in the South Banat region, Serbia, and many more are being developed. All these WFs will affect the same regional bird and bat populations and their habitats, and thus their effects will be cumulative and likely additive. Therefore, we developed a comprehensive methodological framework for quantifying population and cumulative effects on bird and bat species in pre- and post-construction studies. The framework includes: (1) Calculation of the average relative magnitude of each impact, by quantification of the assessed impact of individual WFs (for which such information is available) in relation to their number of WTs or total potential power output (i.e. per WT or MW), depending on the impact; (2) Calculation of magnitude of the cumulative impact of all South Banat region WFs, by extrapolation of average relative magnitude, multiplying by the total number of WTs or total potential power output of all WFs; (3) Assessment and evaluation of cumulative impact, to estimate the effect of the particular cumulative impact on the sustainability of potentially affected population at relevant scale (regional, or higher, as applicable) using Potential Biological Removal (PBR). This framework is applicable in both pre- and post-construction studies. In pre-construction studies, we estimated bird mortality from WTs using the Collision Risk Model (CRM), while bat mortality is not predictable and quantifiable from pre-construction survey data. In post-construction studies, we estimated bird and bat mortality using Evidence of Absence (EoA) software, based on systematic mortality surveys. In both cases, we used PBR to determine the sustainable mortality thresholds of affected bird and bat populations at relevant scale. The PBR is considered an acceptable alternative where Population Modelling is not possible due to the absence of detailed populationspecific demographic data. The PBR was used previously for bird populations but not for bats, although applicable. Then, to assess the sustainability, we directly compared PBR outputs to (cumulative) CRM outputs in pre-construction studies or used PBR outputs as Mortality Threshold in EoA in post-construction studies. Our methodological framework is applicable worldwide, providing that basic population parameters - population size, age at first reproduction, and adult survival (or adult mortality), are available or can be estimated at a relevant scale. Data on age at first reproduction and adult survival are mostly species-specific and available in published sources, while even imperfect population size estimates can be used as far as the uncertainty of confidence interval can be assessed.
Key words: birds, bats, population sustainability, mortality threshold

MICRO-SITING OF MITIGATION MEASURES AT THREE WIND FARMS IN SOUTHERN CROATIA HELP REDUCE BAT MORTALITY AND MINIMISE ENERGY LOSSES

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Mitigation measures aimed at protecting bats at wind farms have become commonplace, usually involving blade feathering and increase of cut-in speed. They have been proven to reduce bat mortality at many windfarm locations and are often prescribed by the governing bodies for new windfarms. We have analysed the effect of mitigation measures at three windfarms in southern Croatia. Government-mandated bat post-construction monitoring programs at these windfarms have shown that bats are being killed, and mitigation measures were implemented after the first year of monitoring. Proposed and implemented measures all included blade feathering and increase of cut-in speed when high bat activity is expected. Results of second-year monitoring at these locations showed very different site-specific efficacy of mitigation measures, from 90 % reduction in bat mortality in the second year to many years of little-changing mortality rates despite continuous tweaks to the measures. The analysis highlights the need for micro-locating mitigation measures within the same windfarm. Many factors need to be considered when designing mitigation measures, including bat activity, species composition, geomorphological features of the surrounding terrain, microclimatic conditions on site, proximity of bat roosts or significant foraging areas and others. All monitored wind farms reduced bat mortality, but with varying results, which can be improved with further site-specific micro-locating adjustments of the mitigation measures. If significant bat mortality is found at a windfarm, not all wind turbines need to be curtailed, but instead effort should be made to determine which turbines have more impact and in what way the measures can be applied to best reconcile the need for energy production and the conservation of bat populations. Cooperation between wind farm operators, bat experts and governing bodies is key in designing mitigation measures that have a measurable impact on bat conservation but barely measurable one on energy production losses.

Key words: bats, mitigation measures, mortality reduction, site-specific

DEVELOPING AND EVALUATING A SMART CURTAILMENT STRATEGY INTEGRATED WITH A WIND TURBINE MANUFACTURER PLATFORM

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Bat mortality at wind energy facilities around the world has resulted in the exploration of numerous fatality minimization measures. The most widely used and accepted is operational minimization (curtailment) that is applied during a set of particular conditions. The standard curtailment regime in North America involves wind speed-based curtailment during the migratory season. However, this method can result in significant power generation reductions when it is applied. The Vestas Bat Protection System (VBPS) is a newly developed software module intended to incorporate additional weather variables into curtailment decisions and increase power generation while maintaining conservation benefits. In 2021 and 2022, we tested the conservation and power generation advantages of VBPS at a 500.8 MW (244 turbine) operational wind facility in southwest Iowa, United States. In 2021 we collected fatality, acoustic, thermal videography, and weather data to determine conditions of highest risk for bat species. To develop curtailment rules, we modeled thermal video bat activity in relation to turbine collected weather variables (wind-direction, wind-speed, temperature) in addition to time of day and week. We found that time of night, week, wind speed, and wind direction had the most influence on bat activity levels. Temperature was the least influential variable. We then conducted a brute-force search over 220,000 covariate combinations to develop simple decision rules that balance power production and bat mortality risk (operation during bat activity). We finalized monthly curtailment rules that incorporated time of night, wind speed and direction for testing in July – October 2022. During this period, the VBPS curtailment rules, wind speed based curtailment, and no curtailment were applied to 36 turbines. Treatments were randomly assigned nightly to each turbine in a balanced randomized block design and daily fatality searches were conducted using detection dogs. We will present results showing the conservation and power implications of weather-based curtailment rules implemented by the VBPS.

Key words: bats, minimization, curtailment, weather

SPATIAL CURTAILMENT: A WIN-WIN APPROACH TO PROTECT BATS IN WIND FARMS LOCATED IN MIGRATION ROUTES AND REDUCE PRODUCTION LOSS

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The case study case is a wind farm (WF) located in an area known for its favourable conditions for wind energy production, driven by maritime activity, solar radiation, temperature, and topography. However, it is also favourable for Pipistrellus nathusii bats migration. An adjustment curtailment mitigation measure was applied to all turbines to reduce the species mortality, however, since P. nathusii uses higher wind speeds for migration, the define cut-in speeds for bat protection are quite high and causes high production losses. Cut-in speeds were determined using an adjusted curtailment method based on wind speed and direction, temperature, time of year, and time of the night to predict activity and its relation with mortality. The aim of this study was to evaluate and identify migratory micro-routes (at WF level) and understand if this could be used as an additional layer of information in the method. The database consists of nacelle height acoustic data, temperature, wind speed and direction from 19 turbines, collected between March and October from 2020 to 2022. The annual average activity recorded per turbine was 303.3 and 788.8 during the spring and autumn migrations, respectively. However, in 2022, there was a significant increase of 54% during the autumn migration over the annual average bat activity. This difference could be attributed to the unusual weather events reported by the country's meteorological service. Despite the increase in activity, the pattern of micro-routes during migration did not change significantly at the WF. The bat activity and cut-in speed data were interpolated and mapped to identify regions with the highest values and results showed differences of WF's area usage during migration: during the spring migration, bat activity was concentrated on the turbines located to the east, closest to the coast. On the other hand, during the autumn migration, the activity was higher in the WF's central area, The turbines located in the south and west areas showed activity up to 75% lower than the other turbines, resulting in cut-in speeds up to 42% lower than those on the migratory micro-route. We propose adding a spatial layer to the curtailment analysis and developing two different curtailment protocols: one for the turbines located in the migratory micro-route and another for the remaining turbines. This win-win approach benefits both bat protection goals and also optimizes inevitable production costs associated with this bat protection measure.
Key words: Adjusted curtailment, bat mitigation, cut-in speed, Pipistrellus nathusii

BREAKPOINT MODEL AS A CURTAILMENT METHOD – A PROMISING ALTERNATIVE FOR ESTIMATING THE CUT-IN SPEED

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Curtailment is a common measure for bat fatalities mitigation during operation phase of wind farms (WF). It involves increasing the cut-in speed to a certain wind speed level to protect bats when they are most active. Different methods exist to determine the cut-in speed: some models use multiple variables such as wind speed, temperature, season, and night-time, to assess bat activity and collision risk to determine the best cut-in speed levels; others are focused on a specific mortality threshold and therefore, establish a relation between bat activity and mortality and use this to determine cut-in speed that will allow reaching a mortality threshold level. Here we present yet another method based on breakpoint models. Its advantage is that it is a simpler alternative that identifies the inflection point of the activity-wind speed curve of bats based on the significant difference between the angular coefficients of the regressions for each interaction. This method can estimate the cut-in speed at which the curve stabilizes and the increase in activity is significantly smaller, making it a better cost-effective option. This study used acoustic bat data from three WFs collected at nacelle height between March and October from 2020 to 2022. Unlike other adjusted curtailment methods, this approach is independent of mortality thresholds as it depends only on the shape of the activity-wind curve. The results showed that the breakpoint outperformed other methods in terms of estimating activity to be protected for all bats species (migrant or non-migrant), with an overall average improvement in 56.3% of the months. Sensitivity analysis showed that the breakpoint performs better in cases where the percentage to be protected is above 90%, which is often the case. Additionally, the breakpoint provides measures of the dispersion of estimates, unlike other tested adjusted curtailment methods and can be applied to cases where two inflection points are present (e.g. in cases where there are two activity peaks in the same curve). The simplicity and effectiveness of the breakpoint model make it a promising alternative for estimating the cut-in speed at WFs. This method has been shown to perform better in optimizing production loss reduction than other methods, however, being a method that is not dependent on mortality threshold, we suggest using this approach when there is no regulation or threshold mortality as a goal.
Key words: Adjusted curtailment, bat mitigation, cut-in speed, break point

IMPLEMENTATION OF ADAPTIVE MANAGEMENT TO MITIGATE NEGATIVE IMPACTS OF WIND FARMS ON BATS – PROBLEM OR OPPORTUNITY?

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Adaptive management is a learning-based management approach that is used to reduce scientific uncertainty. It has been identified as a tool for improving the wind energy industry as it enables projects to move forward by learning from past developments and improving implementation in the future. Generally, adaptive management consists of several steps: 1) assessment of the current conditions and identification of problems, 2) implementation of the management plan that address these problems, 3) monitoring and evaluation of the monitoring results, 4) modification of the management plan according to changing conditions identified through the monitoring process. The implementation of adaptive management in wind farm projects in Croatia is only at the beginning and faces numerous challenges related to 1) professional knowledge in collection and analyses of data on which evaluation of monitoring results are carried out; 2) the willingness of developers to accept adaptable management process even though it might affect project financing and efficiency; 3) lack of legislation that require adaptive management and which is necessary for competent authority to implement changes. Adaptive management is particularly important for designing the most effective measures to mitigate negative impacts on bats. Procedure of EIA for wind farms in Croatia often results in competent authority Decisions which prescribe a mitigation strategy referred to as blanket curtailment based on literature data or bat activity monitoring at one or rarely several locations, often at ground level. Given that fatality risk increases during low wind speed, it includes wind turbine curtailment achieved by raising cut-in speed for most or even all wind turbines during the entire period of potentially higher collision risk. Not only can this type of general mitigation measure create unnecessary losses in energy production, but in certain wind farm locations it can be ineffective in reducing the collision risk and bat fatalities. Unfortunately, the process of amending the prescribed Decisions is legally undefined or not even possible. To ensure that mitigation measures are successful in every sense, it is necessary that curtailment mitigation scheme should be site-specific, which means that preliminary mitigation measures proscribed during EIA should be evaluated, tested and adjusted as needed based on quality post-construction monitoring, which is basis of adaptive management. Current experiences in Croatia have shown that the synergy of the main stakeholders in the process - experts, developers and competent authority - is of crucial importance for the successful application of adaptive approach.

Key words: Adaptive management, impacts on bats, wind farms, Croatia

THE NORTH SEA WIND TURBINE CURTAILMENTS INFORMED BY NEAR-TERM FORECASTS

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The construction of wind turbines along migratory flyways poses a significant threat to vulnerable migratory bird populations due to the increased risk of collisions and alteration of migratory routes. However, the negative impact on birds can be mitigated through various conservation measures, such as the on-demand curtailment of wind turbines during peak migration periods. To make this approach feasible, it is necessary to define periods of intense migration in near-real time in order to accommodate the impact of curtailments on the energy grid. Due to high inter-annual variation in migration patterns, it is argued that near-term forecasts require long-term datasets to be developed. Nevertheless, the high pace of wind energy development does not allow for that and conservation measures must be designed around available data. Here, we present a near-term forecast of low-altitude nocturnal bird migration over the southern North Sea that was developed using tracking bird radar data collected off the western Dutch coast, weather and phenological variables. We show that besides wind assistance, the most important predictors of migration intensity in this region were seasonal phenology in spring and diurnal phenology in autumn. The migration hours were correctly classified by intensity in more than 90% of cases in spring and more than 80% in autumn. We show that to minimize collision risk for 50% of migrants if predicted correctly, curtailments should be performed during only 18 hours in spring and 26 in autumn, which represent 2.5% and 5.5% of the migration period, respectively. In that case, the yearly amount of energy lost due to curtailments would be 0.05% in spring and 0.07% in autumn. We argue that, even though the forecasts are based on data with limited temporal coverage, they can be used in combination with relevant policies to provide a reliable framework for decision-making in bird conservation.

Key words: Curtailments, nocturnal bird migration, radars, migration forecasting

MITIGATION OF RAPTOR COLLISIONS AT TWO AFRICAN WIND FARMS

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As the wind energy industry continues to grow, so does the potential for significant negative impact on at-risk avifauna, such as birds of prey. To mitigate potential collisions, BTE Renewables and Kipeto Energy are applying observer-led Shut Down on Demand (SDOD) using a standard protocol across two windfarms, in Kenya and South Africa, with a second South African wind farm in pilot implementation. SDOD takes place in conjunction with rapid carcass clearing of wildlife and livestock from the sites to reduce vulture foraging. During over two years of implementation the approach has proved effective in minimising collisions of threatened vultures and other priority species. Impacts on the energy output of the wind farms are minimal despite nearly 2000 shutdowns across the platform over this time. Challenges have included training, motivating and managing large teams of observers, as well as the severe drought in Kenya in 2022 that resulted in an overwhelming number of livestock and wildlife carcases (366 on site in October-December 2022), higher passage rates of vultures and increased numbers of shutdowns. Broader benefits associated with the programme include employment of local community members in meaningful jobs, also increasing environmental awareness and a conservation mindset in the broader communities. Effective onsite mitigation alongside offsite conservation activities, currently being implemented with conservation partners across both Kenya and South Africa, are together anticipated to achieve a net gain for target priority species across both countries.
Key words: Mitigation, Raptors, Wind Energy, impacts

DOES A SINGLE BLACK ROTOR BLADE REDUCE BIRD MORTALITY?

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A study on the island of Smøla, Norway, tested whether painting one blade of a wind turbine black reduces the number of bird collisions (May et al. 2020). Although the results were positive for e.g. white-tailed eagle, there is need for a more elaborate study in a more species-rich environment. In September 2021 we started a three-year study in windfarm Eemshaven in the Netherlands. This windfarm is located in an area with high intensity of bird flight movements, resulting in high mortality rates among a wide variety of species. The research is set up following a BACI design (Before–After–Control–Impact) where monitoring of collision fatalities is carried out at a selection of 14 wind turbines. The rotor blades of seven of these turbines were painted black in August – September 2022. Here we present the results of the null monitoring that was carried out between September 2021 and September 2022. The species composition of the fatalities was dominated by gulls and small songbirds, but also several geese, ducks and shorebirds were found. Although we excluded any dead birds from the analysis that were likely to have other causes of death, bird flu may have had an impact, for example when sick and disoriented birds eventually collided with one of the turbines. In total 54 species were found. The number of fatalities was almost equally divided over the impact turbines (still with white rotor blades) and control turbines. A t-test showed no significant difference in the number of fatalities between both sets of turbines. However, at the level of the individual turbines, there are major differences in both the spatial and seasonal distribution of fatalities. These seasonal patterns reflect the migration patterns of waterfowl, shorebirds and songbirds, whereas the spatial patterns probably reflect the location of the turbine and its distance to the coast. The results of the null monitoring give a solid basis for testing the impact of painting one rotor blade black. The impact monitoring is currently running, and at the end of 2024 the final results of the study will be known.

Key words: fatalities, mitigation, black rotor blade, experiment

APPLICATION OF A RISK ASSESSMENT MODEL TO ASSESS ENCOUNTER RATES BETWEEN LARGE WHALES AND SEA TURTLES AND VESSEL TRAFFIC FROM OFFSHORE WIND DEVELOPMENT ON THE ATLANTIC OUTER CONTINENTAL SHELF

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Vessel traffic poses a collision risk to marine mammals and sea turtles. These collisions (i.e., vessel strikes) can lead to serious injury and mortality and is a continuing challenge to the recovery of endangered species such as the North Atlantic right whale (Eubalaena glacialis). There is an overlap between marine mammal and sea turtle distributions with offshore wind (OSW) energy development, which is accompanied by an increase in vessel activity. In some areas, OSW will lead to a substantial increase over baseline vessel traffic levels and will overlap with high seasonal abundances of protected species. Vessel traffic associated with wind energy development therefore poses a collision risk to these species. CSA Ocean Sciences (CSA) together with the Bureau of Ocean Energy Management (BOEM) developed a risk assessment tool to model the potential strike risk associated with OSW vessel operations on large whale and sea turtle species on the Atlantic outer continental shelf. Vessel strike risk is dependent on species density, behavior, and morphology relative to vessel class, speed, and detection efficacy. The risk assessment tool and underlying model determines the expected number of animals at risk for encounter by whale and turtle species based on a user's input criteria, allowing scenario development and comparative testing in an easy-to-use, spatially registered framework. In this application, a series of scenarios were run to assess relative risk for a hypothetical OSW project. Results demonstrate how project design and operational considerations could be assessed to implement vessel risk reduction strategies. The risk assessment tool, therefore, could be used to inform important decision making at the planning, impact assessment, and operational project levels. In addition, coupling the tool with the implementation of emerging new technologies, such as infrared thermal camera systems with artificial intelligence software designed specifically for vessel strike detection and avoidance, will serve as a comprehensive approach to minimizing and mitigating the impacts of OSW energy development. Planning and implementation of these critical features, therefore, represent a multifaceted approach to reducing potential impact to protected species populations and should considered a high priority for regulating agencies and developers alike.
Key words: Marine mammal, sea turtle, vessel strike, risk assessment, offshore wind

BALANCING RENEWABLE ENERGY EXPANSION AND SPECIES PROTECTION THROUGH AUTOMATED RADIO-TRACKING

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The need to transition towards a carbon-neutral society necessitates a rapid expansion of renewable energies. Corresponding plans exist at the national level within the European Union. For instance, Germany has decided to dedicate 2% of its land as go-to areas for wind farms. Recently, the role of species protection has been called out to slow down the expansion of renewable energies, which is leading to the reduction of regulations in expectation to speed up approval procedures. Facing this large-scale infrastructure project, which also affects sensitive natural zones, a cautious perspective on how to balance climate- and species-protection is required. The feasibility of a project-based comprehensive species survey using conventional, analogue methods and few available experts is just as questionable as the abandonment of such surveys in favour of an accelerated expansion of renewable energy. Automating the surveying of species relevant to planning has the potential to resolve this conflict. Recent technological advancements now allow for automatisation in data recording of species relevant to planning, with an automated analysis of the data regarding potential conflicts under species protection laws. This approach not only streamlines personnel and cost requirements but also enhances data objectivity and standardisation. Using automatization of radio-tracking of bats as an illustrative case, this study underscores the potential of automating species data collection to accelerate renewable energy expansion without sacrificing species protection priorities. For the identification of essential foraging areas and day roosts at a species level, the capture, tagging, and subsequent tracking of bats remains indispensable. Yet, manual radio-telemetry is both labour-intensive and time-consuming, yielding limited data outputs. The tRackIT System, an automatic radio-tracking system, enables continuous recording of up to 40 tagged individuals concurrently, with minimal exertion and time commitment. Signals are sent to a remote server in real-time, where they are processed into comprehensible outputs such as localisations, body temperature or individual activity classifications and are visualised as interactive graphics. Over the preceding two years, the tRackIT System has been operational at over 300 planned wind power sites in Germany and has been endorsed as a novel standard by the federal state of Rhineland-Palatinate. Outcomes emphasise the notable enhancement in data granularity facilitated by automated telemetry, translating the database from a few manual telemetry points and survey dates into hundreds of thousands of data points per individual throughout the transmitter's lifespan. This significantly reduces labour and financial outlays, enabling comprehensive survey coverage within existing resource boundaries.
Key words: Bats, automatic radio-tracking, tRackIT System

ASSESSING THE RELEVANCE AND DEMOGRAPHIC CONSEQUENCES OF COMPENSATORY MEASURES FOR SEABIRDS THROUGH EXPERT ELICITATION

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Seabirds represent the most serious risk to consenting in the most important area of UK waters for offshore wind (OW) expansion, the North Sea. OW developments have the potential to affect protected seabird populations by displacement from important habitat, barrier effects to movements, and collisions with turbine blades. In the UK, compensatory measures for OW effects on seabirds are underway, and will become increasingly important in the future as cumulative effects of OW developments become more acute. A range of compensatory measures have been proposed with the potential to completely or partially alleviate deleterious impacts, however, there remains wide uncertainty around the appropriateness of these measures for different seabird species, and in the magnitude of their potential benefit to seabird demographic rates and populations. This is in part due to a lack of empirical data for quantifying the demographic consequences of implementing various compensatory measures, with available data often limited to a single colony or population, or lacking completely for some species. We undertook an expert elicitation to determine the likely effectiveness of different compensatory measures on a range of UK seabird species. We quantified potential demographic impacts of these measures on seabirds, as well as experts' uncertainty about their judgements. Experts first identified 14 compensatory measures for seabirds, with the potential for positively affecting the population demography (breeding success and survival) of seven seabird species/groups in the UK context: black-legged kittiwake, common guillemot, Atlantic puffin, razorbill, northern gannet, large gulls (herring gull, lesser black-backed, great back-backed) and terns (arctic, common, sandwich). Each measure was selected by experts as having likely relevance to at least one of the species under consideration, broadly meaning that they would be likely to have some positive benefit if applied in an appropriate location in a suitable way. The experts then ranked the 14 measures for each species to provide a suite of potential compensatory measures likely to result in some positive benefit. Finally, experts elicited expected changes to seabird breeding success and survival for the suite of compensatory measures identified as relevant for each species. We captured experts' uncertainty in potential demographic consequences via eliciting a distribution for each demographic parameter (breeding success and adult survival) through the quantification of statistical parameters (median values, inter-quartiles, and upper and lower limits). We provide a summary of the elicited results by species, alongside a set of recommendations for the implementation of compensatory measures for seabirds.

Key words: compensatory measures, seabirds, ornithology, expert elicitation

MANAGING IMPACTS OF OFFSHORE WIND PROJECTS: 20 YEARS OF LEARNING WHAT TO DO (AND NOT DO!)

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Over the past 20 years, RWE has been developing, constructing and operating offshore wind projects, with a total installed capacity of 3.3GW across 19 windfarms in the UK, Germany, Belgium, Sweden and Denmark, and almost 18GW in construction and development across Europe, the US and Asia Pacific. RWE's projects have evolved through time, as technology and capabilities have matured, allowing access to a varied range of environments (notably deeper waters, higher/larger turbines, and increasing distance from shore). This has brought new challenges that have been addressed through innovation, knowledge sharing and capacity building. It also enabled new opportunities to develop, implement and share best practices. This paper aims to present RWE's journey through the past 20 years, to share our lessons learnt and best practices to manage impacts of offshore wind. This paper focuses on several examples across multiple projects and geographies at different phases of project development, including: • Commissioning of a Kittiwake tower to support an internationally important nesting colony and to monitor the behaviour and health of the colony prior to the development of the Dogger Bank South windfarm. • Implementing novel bird monitoring techniques using lidar at the Sofia windfarm site in pre-construction phase to accurately measure bird flight heights to improve bird collision risk modelling inputs. • Trialing innovative vibro-piling technique to install low-noise foundations at the Kaskasi windfarm site and reduce underwater noise exposure to harbour porpoises. • Testing innovative anti-corrosion coating on monopile foundations at the Arkona windfarm site during construction. • Adaptive scheduling of construction activities at the Rampion windfarm site to protect spawning Black bream from increased underwater noise. • Designing, construction and deployment of world's first amphibious maintenance vessel at the Scroby Sands windfarm site during operations to address site access challenges from changing sediment deposition patterns. • Using our existing offshore wind infrastructure (floating and fixed bottom) to further understand bird behaviour and test innovative deterrent, detection and tracking technology. • Contributing to maintaining healthy fish and shellfish stocks through several initiatives within and outside windfarms, including the funding of a wild lobster hatchery, supporting the local fishing industry and raising awareness on marine protection and management. This paper also discusses RWE's views on remaining and upcoming knowledge gaps associated with the predicted growth of the sector; innovation needs to ensure continual improvement of impact reduction and mitigation practices; and the need and opportunity for cooperation across multiple stakeholders to scale up from nature-inclusive to nature-positive solutions.

Key words: offshore wind, impacts, leassons learnt, best practice

USING SPATIAL CAPTURE-RECAPTURE TO IMPROVE IMPACT ASSESSMENT ANALYSIS ON LARGE CARNIVORES

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Large carnivores (LC) occupy vast areas and occur at low densities, making challenging to study them and derive robust estimates of their ecological parameters. LC monitoring programs at environmental impact assessment (EIA) procedures should seek to derive quantitative estimates of those parameters before the development of some infrastructure (the reference situation), monitor all the construction phase, and follow, at least, the first years of operation, to make inferences about cause-consequence relationships. This procedure, correctly done, will ensure preventive avoidance/mitigation measures at pre-construction and construction phases, corrective actions at operational phase and/or compensation measures to ensure populational resilience. However, most of the current LC monitoring programs during EIA, despite the vast field effort often undertaken, rely mainly on naïve statistics like relative abundance indexes or absolute survey numbers to make direct assumptions about biological relevant parameters, disregarding the bias from the imperfect observational process. This can lead to incorrect evaluations, dispersion of resources and inconsequent conservation measures. Here, we present a way to overcome present shortcomings by take advantage of the spatial capture-recapture (SCR) framework as a tool to improve impact assessment analysis on large carnivores, using wolf as a model species and examples of a three-year monitoring program. SCR models make explicit use of spatial encounter information on individuals to address questions of a fundamentally spatial nature, such as animal distribution, habitat preferences, movement patterns, spatial connectivity, and dependence of demographic parameters on spatial variables. The formal statistical linkage between the observational process and the underlying ecological processes allows to make unbiased inferences, accounting at the same time for the imperfect detection process. We show that, apart from the need of genetic analysis to create individual information from geolocated scats collected on the field, there is little to change from current wolf survey designs, rather than adjusting the analytical framework. Since SCR results are spatially explicit and allow environmental covariates, it is possible to infer about some infrastructure´s location on the landscape and its potential impacts on LC populations, like exclusion effect (by estimating use of space), barrier effect (by estimating connectivity) or survival (by estimating abundance/density). LC monitoring programs are costly, involve a lot of human and material effort, and many times achieve little data. Making the most from the (few) data collected in the field is a responsibility for everyone involved, so that robust conclusions can be drawn to really help the overall EIA process and safeguard the target species.

Key words: Large carnivores, wolf, spatial capture-recapture, monitoring plans, imperfect detection

POSITIVE STEPS TOWARDS ENHANCING BIODIVERSITY IN WINDFARMS VIA SEAWEED AQUACULTURE

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Offshore windfarms (OWF) are recognised as a key technology to advancing renewable energy generation and the transformation of our energy systems to net zero. However, the installation and running of windfarm infrastructure can lead to localised impacts on the marine environment. As a result, it is important to identify solutions to mitigate any potential adverse effects and contribute to biodiversity net gain via direct intervention. In this study we detail trials assessing the biodiversity benefits and enhancement afforded by a new offshore seaweed farming system, which can be flexibility deployed within OWFs or independently. Here we present our preliminary findings from the assessment of a range of direct and indirect biodiversity metrics, monitored at SeaGrown's seaweed farm in the North Sea (Yorkshire Coast). A feasibility study completed throughout an 8-month period in 2022 trialed a series of monitoring techniques, confirming the viability for deployment within the seaweed system for metrics including for birds, marine mammals and invertebrates. Assessments of invertebrate assemblages directly colonising the kelp, and the influence on benthic invertebrate composition in sediment directly underneath seaweed aquaculture units were assessed through grab sampling. Trials of benthic baited traps confirmed it was viable to deploy units in proximity to the seaweed growing system without impacting operations. The traps allowed for a focused assessment of benthic crustacean and finfish bycatch species assemblages in the study area. Following trialling of 4 systems, a purpose-built underwater camera with real-time viewing capability was found to be the most suitable method for identifying finfish utilising the seaweed within the aquaculture system, We also conducted direct observations of birds and marine mammals to standard methodologies at sites proximal and distal to the farm, allowing real time assessment of interaction with the seaweed farm. To complement the assessment of meio- and macro-fauna, we trialled the use of environmental DNA (eDNA), including panels for invertebrate (sediment) and fish, mammals and bird (water column). Based on verification of these techniques and the identification of optimum methodologies SeaGrown and Ørsted have progressed roll-out of a comprehensive biodiversity assessment for 2023.
Key words: seaweed, co-location, biodiversity

DEVELOPING A MULTIDISCIPLINARY ANALYTICAL FRAMEWORK THAT OFFERS MEANS TO WEIGH TRADE-OFFS WHEN EXPLORING FUTURE WIND ENERGY BUILT OUT AND BAT POPULATION INTERACTIONS

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GOALS: Declines in wind energy costs, technology advancements, and clean energy targets suggest the possibility of a significant increase in wind energy development in the United States. This raises ecological concerns related to population viability for taxa that suffer mortality from collisions with wind turbines. Bat fatalities occur at nearly all wind energy facilities sampled and some species may face risk of imperilment from current levels of wind energy, alongside other stressors. Meanwhile, actions to mitigate these impacts affect where wind energy may be installed and how it may be operated. Quantifying this bidirectional relationship has been intractable to date given challenges related to data access and methodological limitations. To fill this need, scientists from the National Renewable Energy Laboratory, U.S. Geological Survey, and U.S. Fish and Wildlife Service have developed an analytical framework that integrates power sector planning models with ecological models and land and wildlife management considerations to transform our ability to understand and manage renewable energy development while minimizing unintended consequences to wildlife and habitat. METHODS: To accomplish this we (1) incorporated ecologically based siting and operational restrictions in power sector planning models (Regional Energy Deployment System (ReEDS) and Renewable Energy Potential (reV)) that estimate plausible future build out to explore how changes in costs, technology advancements and shifts in policy influence future potential buildout under a suite of variable and complex scenarios; (2) analyzed bat mortality data from approximately 500 individual reports and 260+ U.S. wind facilities relating bat mortality to wind energy technology, habitat, and environmental characterizations; and (3) developed means to estimate impacts to bat populations from the current and future wind energy fleet. RESULTS: Through this work we developed a comprehensive analytical framework to functionally integrate models for power sector planning, mortality analyses, population status and

trends, and demographic models. This framework enables us to estimate population-level impacts under different future build-out scenarios while also more realistically estimating future buildout through improved representation of societal values, laws, and processes related to sustaining wildlife populations and natural heritage. CONCLUSIONS: This multidisciplinary team has overcome methodological and data access challenges to deliver a holistic analytical framework that offers quantitative means to weigh trade-offs of various options related to future wind energy build out and operation, conservation, and natural resource management. Future work will fully integrate these methods in a dynamic analytical framework better representing the temporal interactions and feedback loops in this bidirectional, time-varying relationship.

Key words: bats, population impacts, future build out

TOWARDS ENERGY STEWARDSHIP – A TRANSDISCIPLINARY FRAMEWORK FOR HOLISTIC WIND ENERGY DEVELOPMENT BY BUILDING RELATIONAL VALUES

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Wind energy development has consequences for the natural environment, generally through loss and fragmentation of habitat, direct mortality, disturbance and barrier effects. These impacts can however not be seen detached from human use of the natural environment, i.e. the landscape which is the resultant of a dynamic development of human interactions and utilization of the bio-physical environment in space and time. Landscapes – and the ecological processes they support – are therefore inherently complex socio–ecological systems that encompass a broad range of spatially explicit processes that influence our environments. Throughout its life cycle, wind energy projects affect ecosystem structure and function. In turn, this may affect the benefits (both positively and negatively) people derive from nature such as outdoor recreation and aesthetic values, hunting and fishing opportunities, and habitat for biodiversity. The ecosystem services concept directly associates the environment to the provision of human well-being, a concept to which wind power generation is intrinsically connected. Successful uptake and upscaling of wind energy development therefore requires the societal support for the technology, acceptance regarding the socio-ecological siting of this technology in the landscape as well as the implementation of mitigation measures. The concept of energy stewardship provides a transdisciplinary framework based on the integrated perspective of social-technical-ecological systems. Stewardship is the recognition of our collective responsibility to retain the quality and abundance of our land, air, water and biodiversity, and to manage this natural capital in a way that conserves all of its values, be they environmental, economic, social or cultural both for current and future generations. Stewardship approaches based on building relation and connectedness with the development processes may therefore also support sustainable development of wind energy. We will present how such a framework can be defined. By assessing interactions among the technical, social and natural environments within which wind energy development is set, disciplinary boundaries may better be overcome. This includes reconciling the concepts of energy citizenship, energy landscapes and environmental design. A better understanding of transdisciplinary insights may build trust between different actors, resolve conflicts and ultimately legitimacy for more sustainable wind energy development.
Key words: sustainable development, transdisciplinarity, energy citizenship, energy landscapes, environmental design

MULTIFACETED TRADE-OFFS IN WIND ENERGY PLANNING: ECOLOGICAL VS. SOCIAL, GLOBAL CLIMATE VS. LOCAL PREFERENCE, COSTS VS. CONFLICT AVOIDANCE

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Goal. Motivated by the increasingly complex interactions between wind power and wildlife, a U.S. multi-agency interdisciplinary collaboration was initiated to advance the science on national-scale assessments of how future wind development might interact with wildlife management. An objective of the collaboration is to understand and manage renewable energy (RE) development while minimizing unintended consequences to wildlife and habitat. To accomplish this requires integrating wildlife and land management considerations in wind energy forecasting models and ecological models. This presentation focuses on future energy system planning scenarios used within this research collaboration. Methods. The scenarios consider various levels of stringency to RE siting, and cover a range of energy system decarbonization levels and transmission infrastructure expansion for the U.S. power system through 2050. They are developed using the Regional Energy Deployment System (ReEDS) planning model that optimizes electricity resource portfolios while considering the unique techno-economic characteristics of all generation options, grid reliability needs, and energy policies. For location-dependent and variable RE resources, modeling these characteristics relies on outputs from a separate geospatial model (Renewable Energy Potential), which estimates the resource potential, grid connection costs, and hourly profiles for 67,000 candidate RE locations, to inform the power sector scenario analysis. High spatial resolution enables detailed representation of localized siting factors such as wildlife habitat, proximity to residences, and other land use, technical, regulatory and environmental factors. Siting exclusions are informed by ecological models and wildlife management practices. Results. Our analysis demonstrates how siting considerations impact future renewable energy deployment, transmission needs, and the cost to decarbonize. Stringent siting constraints could preclude availability of high quality wind locations resulting in greater reliance on other energy sources, more-significant transmission expansion to access remaining remote sites, and higher electricity costs. These impacts are particularly acute under low-carbon futures with high demand for clean energy

sources, including scenarios where the wind power fleet expands by more than 5× from today. The analysis is designed to differentiate the impacts between ecologically- and socially-focused constraints on wind development. It also provides plausible wind deployment projections that can be used to estimate impacts on animal populations by combining them with mortality estimates and population dynamics models. Conclusion. Overall, this analysis highlights the tradeoffs between clean energy deployment, wildlife conservation, consumer energy costs, and greenhouse gas mitigation. Such tradeoffs could inform complex decision making in energy, land, and environmental planning.

Key words: energy planning, wind forecasting, siting challenges, scenario analysis, power system modeling

INTRODUCING NEW INTERNATIONAL OFFSHORE WIND METADATA FORMS ON TETHYS

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Tethys (https://tethys.pnnl.gov) is a free online knowledge hub with information and resources on the environmental effects of wind energy. For example, the Tethys Knowledge Base hosts over 5,800 documents on various wind-wildlife topics and the Wind Energy Monitoring & Mitigation Technologies Tool catalogs over 70 different technologies developed to assess and reduce potential wind-wildlife impacts. Supported by the U.S. Department of Energy, Tethys aims to improve access to information to help the international community answer key scientific questions, guide research and development of monitoring and mitigation strategies, and streamline consenting by reducing uncertainty. As part of this effort, Tethys is launching a new resource that gathers information on offshore wind energy farms around the world and the environmental monitoring conducted at each, including links to relevant data and documents. Each metadata entry provides extensive contextual information about the offshore wind farm, features a list of all related reports and studies, and includes details on the environmental monitoring conducted during baseline assessment, construction and operations, and decommissioning (if applicable). When data are publicly available, metadata entries also provide direct links to relevant environmental data that may be distributed across various databases or only available upon request, ultimately improving data discoverability. The Tethys team has partnered with the International Energy Agency's Task 34, Working Together to Resolve the Environmental Effects of Wind Energy (WREN), to collect information for key offshore wind farms around the world. Leveraging over 10 years of experience collecting metadata for wave and tidal energy projects on Tethys, the team initially drafts metadata entries using publicly available information before sending them to offshore wind developers for review and approval. The Tethys team plans to request regular updates from developers to ensure information is up to date and accurate. Collectively, these metadata entries can serve as a reputable and comparable catalog of offshore wind environmental monitoring information that could play a key role in further understanding baseline conditions, monitoring environmental effects, and developing effective mitigation strategies. By making offshore wind environmental information and data more widely discoverable and accessible, Tethys aims to help offshore wind progress in an efficient and environmentally sustainable manner.
Key words: Environment, Offshore Wind, Deployment, Data

A NOVEL APPROACH TO SEABIRD COLLISION RISK MODELLING FOR THE AUSTRALIAN OFFSHORE ENVIRONMENT

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The onshore wind energy industry in Australia has developed specific, robust approaches to data collection and collision risk modelling to account for how birds make use of terrestrial habitats. As the offshore wind industry gains momentum in Australia, we are seeing some of the same lessons and challenges arising again. We have found that many of the insights and processes from the northern hemisphere are not directly transferable. The offshore waters of Australia support a more diverse seabird community than the northern hemisphere, represented by more species and genera, and relatively little is known about their movements, area use and flight heights. A number of these species breed and forage in the areas proposed for offshore wind developments so collision risk modelling needs to account for this mix of resident and migratory use. We present guidance and process for combining data from multiple data streams for seabird impact assessment, including Digital Aerial Surveys, boat-based surveys and bio-logging studies, demonstrating the importance of utilising a number of complimentary survey methods. We highlight specific adaptions from northern hemisphere approaches to species apportioning, combining digital and observer data for flight heights, and adjustment methods for the relative speed of birds and survey aircraft. This methodology includes the empirical derivation of time-based flight flux (e.g. flights per hour per km2) from digital imagery. This allows us to calculate the probability of interaction with a turbine location without resorting to additional assumptions about bird flight speeds. This has a number of advantages, avoiding counter-intuitive results like higher flight speeds result in a higher collision rate due to the influence on the flux rate calculation (see Masden et al. 2021). For the Biosis model, flight speed only influences the probability of collision after a flight has interacted with the turbine region. We compare and contrast Australian ecology and these methods with Northern Hemisphere approaches and provide guidance for other practitioners working for the Australian offshore wind industry.

Key words: Offshore wind energy, seabirds, collision risk

IMPLEMENTATION AND MONITORING OF KEY SPECIES INTERACTIONS WITH NATURE INCLUSIVE DESIGN PROJECTS IN NORTH SEA WIND FARMS: THE BORSSELE COD PIPE PROJECTS

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Offshore windfarms (OWF) are recognized as a key technology to advancing renewable energy generation and the transformation of our energy systems to net zero. However, the installation and running of windfarm infrastructure can lead to localized impacts on the marine environment. As a result, it is important to identify solutions to mitigate any potential adverse effects and contribute to biodiversity net gain via direct intervention. In this collaborative study we detail a trial project to identify the biodiversity benefits and enhancement afforded by the installation of cod pipes and scour protection, an artificial reef system located between the Borssele 1 & 2 offshore wind farms in the Netherlands, which can be flexibility deployed within OWFs or independently. In this case, reefs were deployed in 2020, 4 reef structures, around 45 pipes, in a circular reef formation. Here we present our preliminary findings from a preliminary study completed throughout an 18-month period in 2021 that trialed multiple monitoring techniques and assessed viability for deployment of cod pipes based on vertebrate and invertebrate behavior patterns and seasonal stays. Deploying a network of 16 acoustic telemetry receivers mounted in tripod frames, coupled with 64 individually tagged Atlantic cod (Gadus morhua), the monitoring was ran for 18 months across 2 consecutive summer seasons. In May 2022, the acoustic receivers were retrieved and deployed again. The data collected provides GPS coordinates through time, providing detailed information on behavior, area utilization, and attachment to structures via fine scale positioning at location for each individual fish. eDNA water samples helped illustrate development of species diversity on the artificial reefs. Results show an overall strong attachment (high fidelity) to the artificial reef. Additionally, over the same period, a total of 24 European lobsters (Homarus gammarus), were also fitted with transmitters and released. Maps of invertebrate behavior received from the transmitters revealed that, while most of the lobsters left the site within a day, a small number used the artificial reef and its immediate surroundings for a few days, but then migrated on. This research suggests that it is viable to deploy units in proximity to offshore wind farms and provide habitat and foraging features for key species without impacting operations. Based on these preliminary results, Waginingen University, Der Rijkenoordzee, and Ørsted have progressed a second research cycle in 2021 for which data is currently being analyzed. The study will run until the end of 2023.
Key words: nature inclusive design, telemetry, artificial reef, lobster, cod

MONITORING OF WINDPOWER SPECIES-SPECIFIC IMPACT DURING OPERATION – EXAMPLES FROM SWEDEN

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The goal for the study was to see if operators of windpower farms in Sweden fulfill their obligations to monitor effects on species. When permits are issued for windpower farms in Sweden, it is under the prerequisite that there will be no significant effect on the conservation status on protected species (birds, bats, lichens etc.). In order to avoid unforeseen damage, conditions for investigations and monitoring are issued in the permits. We analyzed how these follow-up requirements are regulated in a formal sense in the permits during a recent period. Thereafter we have investigated how the control is performed in a number of permits for installations now in operation. In Sweden monitoring is biased towards birds and bats, especially those present in the forest landscape in the northern part of the country where wind farms often are established. Our results show that the conditions in the decisions are very general and only regulate the monitoring of the species (not nature types or fragmentation effects). Conditions concerning monitoring, or protective measures, regarding species are more frequent during the construction phase than the operation phase. Conditions for follow-up is often on short-term, usually 1-3 years after start. These deficiencies result in difficulties in demonstrating the effect of the individual wind farm in relation to other environmental effects (wheather, forestry etc). In particular, long-term effects of operations, as well as cumulative effects between several wind farms, are difficult to assess. The supervisory authority may order the permit-holder to undertake further investigations or investigations covering other concerns than those covered by the conditions in the permit, but this rarely happens. To this background, we conclude that the Swedish system for permits for wind farms lacks a systematic control of effects on species and nature types and therefore does not meet the updating requirements in EU law. We therefore propose: • Longer time series for control, preferably during the entire operating phase (30-35 years). • Control against population status outside the wind farm at regional or national level, and preferably coordinated inventories of several wind farms. • Also the use of accepted methodology that allows statistical tests and finally open storage of data so that data can be verified and reused.

Key words: Monitoring, impact, law, supervisory authority

THE RICH NORTH SEA: LESSONS ON NATURE ENHANCEMENT IN OFFSHORE WIND FARMS

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The Dutch North Sea used to contain hard substrate such as large oyster reefs, gravel fields and moorlog banks. Due to (a.o.) mining, dredging, diseases and (over)fishing, hard substrates have drastically decreased during the 19th and 20th centuries. Currently environmental targets are not reached in the North Sea while in the coming years, many offshore wind farms (OWFs) will be built. OWFs are promising locations for nature enhancement and reintroduction of biogenic reef species in the North Sea. They offer hard substrate surfaces and often, less bottom habitat disturbance. The Rich North Sea programme aimed to enhance nature in OWFs by creating reefs and increasing biodiversity. By running projects in different (OWF) locations and testing artificial reef structures in an offshore test site, joining in scientific projects, creating a stable flat oyster breeding line and lobbying towards nature enhancement in legislation, the programme aimed to reach these goals. By creating an online platform (the "Toolbox"), knowledge sharing is enabled. The programme is in its last year and the focus is now shifting to the long term: how to keep implementing nature enhancement options and nature inclusive designs into an even busier North Sea? How can we balance the benefits of offshore wind with the opportunities (and risks) to the natural environment? The presentation will go into the projects of The Rich North Sea as examples for the future, using the mitigation hierarchy to give insight into what we think are logical next steps. This includes recommendations and examples such as the use of non-price tender criteria focused on ecology, a long-term vision for North Sea nature on a sea-basin scale and using the industrialisation of the North Sea to fund its restoration.

Key words: nature enhancement, offshore wind, lessons learned, practical, artificial reefs

PILOTING A SEASCAPE-SCALE RESTORATION APPROACH

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Goal: An innovative ‘seascape’ scale restoration programme for the Humber Estuary, by supporting the reestablishment of a series of transitional coastal habitats in their natural succession chain, and the robust assessment of the restoration’s biodiversity impacts. Material and methods: The targeted restoration of two sites, both encompassing opportunities for reconnecting a series of coastal habitats, with specific interventions based on site conditions: Site 1: Chalk Bank – focus on restoration of 5 hectares, reestablishing connections between fragmented saltmarsh, seagrass, native oysters and sand dune. We are working on the restoration, improvement and biodiversity enhancement of at least 1 ha of saltmarsh, 2 ha of seagrass, and the laying of 250,000 native oysters over a 2 ha area with improvement to 1.5 acres of sand dune. Site 2: Horseshoe Point – focus on the restoration, improvement and biodiversity enhancement of at least 2 ha of saltmarsh, 2 ha of seagrass and the introduction of 250,000 native oysters into a sparse cockle bed with historic records of oyster presence. A suite of biodiversity, water quality and ecosystem service monitoring studies are underway to qualify and quantify the impact of this combined seascape restoration. Results: By the time CWW begins in September, we will be able to share the results of the first restoration work as well as details on the baseline and the seascape restoration approach used for both sites. Conclusion: This project builds on an existing seagrass restoration initiative initiated by Orsted’s Hornsea 4 project which has already restored close to 5Ha of seagrass habitat. It underscores the need for ‘seascape’ approach to restoration in order to ensure resilience, and demonstrates how this might be achieved and scaled-up.
Key words: Native oysters, seagrass, saltmarsh

THE OFFSHORE COALITION FOR ENERGY AND NATURE (OCEAN)

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GOAL The Renewables Grid Initiative (RGI) is a unique collaboration of environmental NGOs and transmission system operators (TSOs) from across Europe promoting fair, transparent, and sustainable grid deployment. In 2020, due to the big push offshore wind energy (OWE) has received and the urgent need to tackle the biodiversity and climate crisis, RGI formed a coalition including NGOs, wind developers and TSOs, called the Offshore Coalition for Energy and Nature (OCEaN). Our goal is to enable a collaborative approach to accelerate offshore wind and grid deployment hand-in-hand with the protection and restoration strategies. The Coalition gathers 29 organisations working together to fill knowledge gaps on the potential impacts of offshore wind farms (OWFs) and their accompanying grids on marine biodiversity. Specifically, we aim to explore: 1.Ways to avoid and mitigate adverse environmental impacts of OWFs and grids, 2.Nature restoration potential within OWFs, 3.Co-location of OWFs within environmentally sensitive areas. METHODS OCEaN provides an open forum where existing information and experiences are collected and assessed. We identify further research needs and jointly design solutions on how to speed up the deployment of OWE and grid infrastructure while preserving and restoring European seas. The work of OCEaN is divided into thematic task forces to improve linkages between the EU, national and regional levels and guarantee the delivery of joint positions and publications. RESULTS Since its formation, OCEaN has been striving to act as a trust-building platform where common language and positions (e.g., Statement on the Restoration Law) can be found between stakeholders with often conflicting interests. Therefore, several outputs were published, such as the 'Case study on marine environmental data monitoring for nature-friendly offshore wind' and 'Essential environmental concepts for the offshore wind energy sector in Europe' discussion paper. New publications are being developed, focusing on mitigation measures and co-location. Considering the complexity of aforenoted topics, OCEaN wants to engage with stakeholders beyond its coalition, including scientific community. CONCLUSION Trying to achieve energy transition without equally addressing biodiversity and climate crisis could lead to exacerbating one of them further. Currently, knowledge on the relationship between OWE and environment is either missing or fragmented. However, this should not hinder efforts to achieve environmentally-sound energy transition. Rather, it should inspire various stakeholders to collaborate, share and promote their knowledge and good practices. By acting as a bridge between stakeholders, OCEaN wants to facilitate this process and therefore contribute to safe and sustainable renewables deployment.
Key words: Offshore wind, collaboration, Industry, NGO, Biodiversity protection

KEY CUMULATIVE BIODIVERSITY RISKS, CURRENT ISSUES, FUTURE OUTCOMES, AND RESEARCH GAPS IN JHIMPIR WIND REGION (JWR), PAKISTAN

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The Jhimpir Wind Region (JWR) is one of Sindh, Pakistan's most promising wind energy potential locations for electricity generation. It spans an area of 9700 km2 and has an emergent power potential of 43000 MW, out of which 1645 MW are presently supplied to the national grid. The intricate web of wind tower installations and the network of overhead transmission lines (OHL) are responsible for the rising cumulative consequences on resident and migratory bird and bat species within JWR. Owing to insufficient technique adaptation for bird and bat monitoring, incorrect evaluation, and a lack of technical skills, knowledge concerning these consequences remains questionable. Data from 16 of 32 projects indicated that none of the projects performed monitoring and assessment with appropriate methodology for Post-Construction Fatality Monitoring (PCFM), potentially resulting in a lack of data on the number of bird and bat fatalities impacted by wind turbines. The presence of globally threatened species, as well as other resident and migratory species, were stressed in all of the investigations. In accordance with the bird and bat studies conducted in the project area, there are 636 resident birds, 190 migratory birds, which are further subdivided into 17 globally threatened species (11 raptors), and 4 species of bats that may have been impacted by the current operation and expansion of wind turbines. The qualitative approach was used to assess cumulative impacts, and key impacts identified due to wind farm expansion in the JWR include incremental change in critical habitat, catchment areas due to leftover construction debris, inadequate waste management near substations, disturbance due to the growing number of spot lights and avian lights for diurnal species, expansion of human settlements near the JWR, soil erosion and loss of fertility due to vehicle movements, selling of species (raptors, passerines, and water birds) in unregulated markets, and a surge in hunting and poaching activities. The key biodiversity risks anticipated include loss of critical habitat, elevated vulture collision risk, disturbance or barrier effects on resident raptors, low migratory bird influx, and population decline of flora and fauna. The main objective of this research is to identify the cumulative key biodiversity risks/ effects in the study area, as well as their proposed mitigation measures, assess the ongoing data acquisition model for PCFM, and identify current issues, future outcomes, and research gaps.
Key words: Renewable Energy, Biodiversity risk, Bird monitoring, Project issues, research gaps

REFLECTIONS FROM THE SOUTH. LESSONS FROM OVER A DECADE OF ADDRESSING WIND ENERGY'S IMPACTS ON BIRDS IN SOUTHERN AFRICA.

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*** NOTE: This is proposed as a pre-recorded presentation**** The impacts of wind energy on biodiversity have been studied extensively in the USA and Europe, but emerging markets may face different challenges. In South Africa, the Birds and Renewable Energy Specialist Group (BARESG) is an independent advisory group formed by bird conservationists and ornithologists to mitigate the impact of renewable energy on birds. BARESG was established in 2011 to support the anticipated growth in wind energy infrastructure linked to the independent production of renewable energy for the South African grid. Subsequently, BARESG has developed tools and resources to support assessment and mitigation, and has provided a platform for researchers, consultants, and NGOs to exchange information and ideas during a growing national energy crisis. We draw on BARESG's collective insights and reflect on key lessons learned to guide stakeholders in countries initiating wind energy developments. These lessons include: 1.) Battles avoided are better than battles won. Good science and robust guidelines can dissuade developers from investing in inappropriate locations. 2.) Identifying collision-prone species and sensitive spaces (e.g., sensitivity mapping) can be a helpful initial step. 3.) Impact assessments and mitigation strategies must be supported by scientific literature and underpinned by robust baseline data. International best practise can act as a guide where local data are lacking. 4.) Risks may change over the lifespan of a wind farm. Be aware of data limitations. 5.) Raptors and vultures are most at risk but don't forget the small guys! 6.) Do not underestimate the value of post-construction monitoring and information sharing to test assumptions and innovative mitigations. 7.) Don't overlook associated infrastructure. Powerlines have significant impacts, easily minimised with appropriate planning and design. 8.) Consider the compliance and enforcement capacity of authorities. Are mitigation measures going to be implemented in practice? 9.) Expensive technological mitigations are not always preferable to well-trained human observers and low-tech solutions, especially in less wealthy nations. 10.) If the industry is competitive and driven by private power producers, use them to unlock resources for research and conservation action beyond the development footprint. 11.) By facilitating the

sharing of knowledge and expertise and promoting responsible practices, independent advisory groups like BARESG can help address the impact of wind energy on birds.

Key words: Emerging markets, Africa, implementation, wind energy, birds

PHENOLOGICAL ASPECTS OF CROATIAN BREEDING BIRDS; CONTRIBUTION TO REGULATORY AND PLANNING ASPECTS OF WIND ENERGY PROJECTS

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Energy is a key factor in human development that ensures modern existence and standard of living, with electricity one of its most important forms. The most important energy sources in the 21st century will be alternative or renewable energy sources, among which wind power currently looks like the most promising, with it already being a significant source of electricity. The increasingly frequent planning and construction of wind farms has imposed the need for more systematic research into their impacts on the environment. The most obvious direct impacts on birds include fatal and non-fatal collisions with wind turbine structures, habitat disruption and its loss, and behavioural displacement. Although numerous wind farms have been built in the Republic of Croatia, there is still a considerable difference in opinion regarding their impact on birds. To date, 240 species of breeding birds have been recorded in Croatia, out of a total of 403 recorded species. Of these, 88 are breeding bird species endangered at the national level, as listed in the Red Book of endangered bird species in Croatia. The authors have been working on various projects for many years, during which time research on human influences on birds has been carried out. Due to the diverse and valuable types of habitats and increasingly frequent interventions in nature. there was an identified need for tabulated information that would summarize data on the seasonal breeding period of the 88 breeding bird species in Croatia. The breeding phenology for each species is presented in the table order to inform decision making and reduce the risks of planned projects in sensitive natural areas. The table shows each species' most sensitive time periods, relating to the beginning and end of the breeding season in Croatia. The start of the breeding season is defined as the approximate earliest date of territory/nest establishment and egg laying and the end of the breeding season is defined as the approximate latest date of which the fledged young leave the breeding territory. Due to constant changes in nature and increasingly pronounced climatic extremes, there will probably be less deviations and less variability in the breeding season. In the table, breeding season months are divided into three periods of roughly 10 days in length. The aim of this work is to inform strategic planning of wind farm projects, to minimize the risk to target breeding bird species that are important for the ecological network.
Key words: breeding,birds, season dates Croatia,

TESTING HABITAT SENSITIVITY MAPS FOR LARGE CARNIVORES FOCUSED ON THE RESULTS OF GREY WOLF MONITORING BY CAMERA TRAPS PRIOR TO THE CONSTRUCTION OF WIND FARMS – A CASE STUDY FROM CROATIA

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In order to assess the impact of planned wind farms (WF) on large carnivores (LC), the "Technical manual for the assessment of project impact on large carnivores either individually or within planning documents - example windfarms" was published in 2016, which contains habitat sensitivity maps for large carnivores for the territory of the Republic of Croatia. The suitability of the habitat was determined by mathematical modelling in GIS software using data on the occurrence of large carnivores and associated habitat features (number of ungulate species, distance to roads, settlements and forests, altitude and slope of the terrain, proportion of agricultural land, etc) and classified in classes from 1 (not suitable, i.e. the probability of LC occurrence is between 0 and 5%) to 9 (highly suitable, i.e. the probability of LC occurrence is between 80 and 100%). As only the grey wolf is permanently resident in most of the areas where large carnivores were monitored, the comparison of the results of camera trap surveillance with the habitat sensitivity maps is conducted only for the grey wolf. Monitoring was carried out for nine WFs, i.e., a total of 270 camera traps in different habitat sensitivity classes were set up in the wider surroundings of 16 or 21 km of the planned WFs. The results obtained showed the uniformity of wolf occurrence by categories of habitat sensitivity classes (51.8% wolf occurrence in unsuitable and low suitable habitats (classes from 1 to 3), 41.7% occurrence in moderately suitable habitats (classes from 4 to 6) or 45.2% wolf occurrence in highly suitable habitats (classes 7 to 9). These results only refer to positive results, i.e., whether the camera trap recorded the presence of a wolf in a certain habitat class or not. A detailed analysis of wolf occurrence will be presented regarding the number of active days of the camera trap, the frequency of wolf occurrence and the ratio of certain habitat classes in the wider area of the planned WF. The uniform occurrence of wolves detected by the camera trap method, regardless of habitat suitability according to the existing habitat sensitivity maps, could be a consequence of a significant change in habitats due to the cumulative effect of the infrastructure facilities constructed after 1.1.2015 forcing the wolf to use less suitable habitats. Furthermore, these results indicate a need for updating the existing habitat suitability maps.

Key words: wind farms, grey wolf, camera traps, habitat suitability modelling

PERFORMANCE OF THE BIOSIS WIND TURBINE AVIAN COLLISION RISK MODEL EVALUATED FOR TWO SPECIES OF AUSTRALIAN EAGLES

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Avian collision risk models have been used extensively to forecast the potential for birds to collide with wind turbines and provide an estimate on the number of collision mortalities for specific species. While this information is a crucial part of environmental impact assessments, validation of model performance requires a comparison between forecasted collision and actual observed collision rates. The latter requires post-construction mortality data that is sufficient to permit calculation of an actual annual mortality rate. These data are often difficult to obtain owing to carcass decay rates, the capacity to locate carcasses and various spatiotemporal constraints in search effort. Therefore, it is likely that only a portion of the actual collision related mortalities are documented. Large avian predators such as eagles may be good model species to validate collision forecasts as these species often have a high collision rate are readily detectable by searchers and, in the case of an Australian species, their carcasses have been shown not to be favoured by scavengers. The Biosis collision risk model was developed in the early 2000's and has subsequently been employed to forecast avifauna collisions at a multitude of proposed wind energy facilities in Australia. In this study, the Biosis model was used to provide projections of potential collisions by Wedge-tailed Eagle and White-bellied Sea-eagle for three Tasmanian wind farms) and for Wedge-tailed Eagle at one Victorian wind farm. Modelling was applied using a range of avoidance rates. At all four sites, intensive carcass searching was undertaken allowing for comparisons between model predictions with empirical mortality data. Across all sites and avoidance rates, forecasts from the model were accurate to within less than one Wedge-tailed Eagle collision per annum when compared with collisions recorded from carcass searches. For White-bellied Sea-eagle, model predictions were more accurate to within less than 0.1 collisions per annum when compared with actual collisions. These results provide novel information on the utility of collision risk models to real-world applications. It is currently not feasible to make similar comparisons for most bird species that may interact with wind developments in Australia. However, design refinements to carcass search regimes as well as improvements in analytical methods for collision estimates may provide suitable information to address these uncertainties.

Key words: Collison risk modelling, eagles, avoidance

INCLUSIVE DEVELOPMENT OF WIND ENERGY AND RELATED INFRASTRUCTURE: USING COLLABORATIVE SCIENCE AND STAKEHOLDER ENGAGEMENT TO REDUCE RISK TO WILDLIFE IN THE ARID SOUTHWESTERN UNITED STATES

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Many areas in the southwestern United States suitable for utility-scale wind energy development currently lack the infrastructure needed to bring power to market, creating a significant impediment to achieving climate goals. Because of the arid nature of the southwest United States, riverine and riparian corridors serve as crucial resources for wildlife, and wind energy facilities in the region must deliver power utilizing transmission infrastructure that cross one or more of these vital wildlife areas. The Middle Rio Grande Valley of New Mexico serves as critical wintering habitat for tens of thousands of sandhill cranes (Antigone canadensis), and multiple high-voltage transmission lines that deliver power from planned, under construction, and/or operational wind energy facilities in central New Mexico cross or are planned to cross the Rio Grande, potentially impacting this species. Wintering sandhill cranes in the Middle Rio Grande Valley are also an important socio-economic resource, and local opposition to wind energy development and associated infrastructure is often based on perceived impacts to this species. To better understand the risk to wintering sandhill cranes posed by the SunZia Transmission Project, which is proposed to cross the Rio Grande to deliver power from extensive wind energy installations in central New Mexico, we engaged in a collaborative study with the United States Fish and Wildlife Service utilizing data derived from a long-term telemetry-based monitoring program. We used approximately 160,000 in-flight locations to determine flight heights and calculate passage rates of sandhill cranes, then used regression modeling to develop a landscape-level map identifying potential hotspots of risk. We showed that in many areas, the likelihood of significant impacts to sandhill cranes is extremely low. We also engaged stakeholders from local environmental non-governmental organizations, many of whom were historically opposed to the Project, to share the results of our study and better understand continued concerns. This engagement led to wildlife-related minimization measures for the Project that exceed industry standards, and when informed by the results of our study serve to effectively "de-risk" portions of the Project. We demonstrate that an inclusive approach, grounded in robust, collaborative science and supported by recurring stakeholder engagement, can facilitate development of the critical infrastructure needed to support the continued growth of wind energy to help meet climate goals in the United States.
Key words: inclusive, collaborative, stakeholder, cranes, infrastructure

To Content

POSTER PRESENTATIONS

CONTROLLING WHO CONTROLS: UNVEILING UNDERESTIMATES OF BIRD AND BAT FATALITIES AT WIND FARMS IN CENTRAL SPAIN.

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We analyzed the fatality monitoring of 44 wind farms accounting for 1,000 turbines in Soria province (2002-2021). PCFM is mandatory for the lifespan of any project according to environmental consent. A database of fatalities accounted for the date, species, coordinates, wind farm, and turbine; we also peer-reviewed all the reports related to impacts on birds and bats considering an existing PCM protocol. There were 5,373 fatalities of 5,020 birds and 353 bats involving 138 and seventeen species respectively. Raptors excluding vultures were the most affected group (2,435 individuals and twenty-four species); only 1% of the individuals were nocturnal belonging to three species. Vultures accounted for 1,931 fatalities. Among "passerines" steppe birds (larks) were the most abundant (14%), regardless which habitat the wind farms occupy. Results allowed a cumulative analysis for species like the Griffon vulture and the Lesser Kestrel, but numbers have to be treated with caution. We calculated yearly observed fatality rates (OFR) for four bird sizes: vultures, large birds (larger than a kite), medium (Sparrowhawk to pigeons), passerines and associated sized (swifts), and bats. With the average OFR for each wind farm we developed nested GLM models considering the OFR as a dependent variable and vegetation cover, turbine type (blade length and hub height), number of turbines, developer, and time devoted for PCFM on each visit. Vegetation resulted in a non-significant variable across all the models, which was subsequently removed. GLM showed non-significant differences for vultures and any of the variables, probably because they are easily visible and detectable. Searching time negatively affected the OFR, especially for the smaller carcasses (passerines and bats), due to tiredness and a lack of proper fatality searches. The number of turbines increased the OFRs but only for one developer. This is an important finding, having implications when developing a PCFM protocol and controlling how does consultancies perform fieldwork. The bigger the wind farm, the more OFRs is detected for large birds and passerines. The existing PCFM protocol must be adapted to the current scientific knowledge. There is still a need for control of the fieldwork, which finally depends on several internal –e.g. monitoring skills and training-, and external -monitoring proposals and budgets- factors. These require the alignment of government, developers, and consultancies for a real benefit to biodiversity and appropriate mitigation measures. The collection of databases is not enough without proper Due Diligence of the PCFM work which is rarely done.
Key words: Post-construction, fatalities, protocol, biases

INTRODUCING OFFSHORE WIND ENERGY INTO THE SEA SPACE, METHODOLOGY AND TEST USE-CASES ARCHIPELAGOS OF AZORES, MADEIRA, AND THE CANARY ISLANDS

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The recent development of floating facilities has made Offshore Wind Energy (OWE) an option for the previously non-attractive sites to become economically suitable locations for energy production, especially for European outermost regions, the Canary Islands, Azores, and Madeira. This study applied a novel approach for introducing OWE by determining the most suitable locations considering the following five clusters: oceanographic potential, environmental sensibility, (in) compatibilities related to marine conservation, and potential conflict with current maritime activities and coastal land use. Study compared the results of the Canary Islands' suitability analysis (45 000 km2) with those of the recent studies on the Azores (37 500km2) and Madeira archipelago (12 500 km2), to design the required data framework for analyzing initial conditions and to finalize multi-criteria analysis concepts, a method for OWE introduction. To manage an elevated number of parameters, we used Decision Support System INDIMAR, a publicly available web application, in which we introduced initial conditions, selected parameter models, and calculated related weights (significance) by applying pairwise comparison and analytical hierarchy process. As major outputs, the required data framework is defined for analyzing initial conditions, the schematic definition of a reproducible methodology for applying the suitability analysis, necessary for defining the strategy for introducing or extending OWE sector.
Key words: Offshore Wind Energy, Decision Support System, Suitability analysis, Data framework, Multicriteria analysis

STRENGTHENING ENVIRONMENTAL ASSESSMENT FOR WIND DEVELOPMENT BY INTEGRATING THE HUMAN ELEMENT: A RISK MANAGEMENT APPROACH

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Consideration of wildlife and biodiversity issues during development of wind energy projects is typically driven by regulatory/consenting requirements, lender/financing requirements, or corporate sustainability commitments. Regardless of the driver, even the most technically rigorous biodiversity studies and "watertight" environmental consenting processes can be disrupted by concerned stakeholders if projects/developers lack "social license to operate", if stakeholders feel their environmental concerns have not been adequately addressed, or if stakeholders are seeking an outlet for non-environmental grievances they have not been able to communicate effectively through other channels. Although stakeholder engagement is often conducted as a public relations activity or to support socioeconomic assessments, stakeholder interests may include environmental, biodiversity, or wildlife issues that are more complex than simply conservation. These interests could be driven by traditional environmental knowledge and/or cultural practices, benefits from ecosystem services, outdoor recreation interests, economic interests, and/or cultural values and identity. Consideration of these socio-environmental interests can serve to enhance wildlife and biodiversity studies, support integration of concerns into project design and engineering, support identification of strategic partnerships, and/or reduce the likelihood that environmental concerns could be used as a proxy issue to disrupt development due to wider anti-renewables sentiments. Thus, developers should actively take a holistic approach to assessment, mitigation, and management of environmental, biodiversity, and wildlife issues that considers the human environment alongside wildlife and biodiversity considerations. Adopting this approach can lead to streamlined environmental approvals and regulatory processes, increased compatibility with external lender and regulatory frameworks, increased social license to operate, and opportunities for targeted nature-based solutions and nature-inclusive design. This approach is also compatible with Nature Positive goals, ensuring that critical energy transition projects can be implemented equitably to ensure positive outcomes for both people and nature. In this talk, we will present a framework for success including approaches, tools, timelines, and best practices to integrate social considerations into environmental assessment for the enhancement of environmental assessment and stakeholder engagement, drawing on case studies from renewable and extractive energy projects worldwide.

Key words: stakeholders, finance, engagement, socio-environmental

USE OF HEIGHT ANNOTATED MAP-BASED AIDS AS A TOOL TO IMPROVE SURVEYOR FLIGHT HEIGHT ESTIMATES DURING VANTAGE POINT SURVEYS

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To meet 2030 renewable energy targets, there is a need to accelerate deployment and/or re-powering of onshore wind energy in Ireland. Given wind energy development can have negative consequences for wildlife, it is necessary that development proceeds in an environmentally sustainable manner so as not to simultaneously exacerbate the biodiversity crisis. To ensure such sustainable development, consenting decisions regarding wind energy development should be based on best available evidence regarding potential ecological impacts. Impacts of wind energy development on birds have been of particular interest due to the potential for fatal collisions between birds and the turbine structure. Estimates of the height of birds in flight are critical to understanding the risk of these collisions as part of impact assessments and appropriate mitigation strategies at wind farms. Bird flight height is typically estimated visually by surveyors during vantage point surveys. Despite the importance of this parameter for a robust impact assessment process, the accuracy of surveyor flight height estimates remains untested. Evidence from published literature suggests that surveyor flight heights are inaccurate relative to sensor-based tools (Hardwood et al., 2018; Becker et al., 2020) but these tools are often not easily incorporated into standardized survey protocols (Harwood et al., 2018) and/or provide data that is not directly suitable for the subsequent assessment of potential impacts (Becker et al., 2020). Potential tools for aiding surveyor estimation of bird flight height should therefore be easily incorporated into established survey protocols and provide data that is relevant to the assessment process. In this context, height-annotated map-based aids may provide a useful tool to aid surveyor flight height estimates but hitherto remain untested. Therefore, we aimed to quantify the accuracy of surveyor flight heights and the influence, if any, of the height-annotated map-based aids on surveyor flight height estimates. To do so, flight height estimates from trials where surveyors, grouped by access to height-annotated map aids, were compared with those of an unmanned aerial vehicle (UAV) used as a test target and a source of accurate (GPS) flight height data. Other factors which may influence surveyor flight height estimates, such as surveyor experience, were also accounted for. Preliminary results suggest surveyors find the map-based aids a useful addition to vantage point surveys.

Key words: flight height, vantage point surveys, wind energy

REGIONAL ASSESSMENT OF OFFSHORE WIND IMPACTS ON AVIFAUNA IN CANADA

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Recently, the Canadian government has signed agreements to conduct regional assessments of offshore wind power development along the Atlantic coast. Impacts on avifauna (migratory birds, species at risk) are a potential concern in Canadian waters as some species are known to be particularly vulnerable to offshore wind turbines. This poster reviews the current state of offshore wind development in Canada and how Canada approaches the regional assessment of potential impacts on avifauna, specifically migratory birds, bats, and species at risk. We draw upon Canada's regulatory mechanisms, existing literature, and ongoing research to identify critical areas of concern and gaps in knowledge. Our poster aims to provide a comprehensive overview of how Canada is assessing potential impacts of offshore wind development on migratory birds, bats, and species at risk and informing decision-making around the sustainable development of this emerging industry.
Key words: Offshore, Canada, Migratory Birds, Avifauna, Species at Risk

REPOWEREU AND GO-TO AREAS IN THE MEDITERRANEAN BASIN COUNTRIES: PERSPECTIVES FROM GREECE AND PORTUGAL

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REPowerEU builds on the full implementation of the Fit for 55 proposals tabled in 2021, with the ambition of achieving at least -55 % net GHG emissions by 2030 and climate neutrality by 2050, in line with the European Green Deal. To deal with this transition scenario, the European institutions work towards a set of amendments to the Renewable Energy Directive to accelerate permitting process, including simplification of the Environmental Impact Assessment procedure, and mapping the Go-to Areas. Efforts have been made to translate EU policy directions and legal documents at the national level. Greece and Portugal committed to achieving 35 and 47% respectively of gross consumption from renewables in 2030 (NECP). Currently, the NECPs and the relevant legal framework are under review and Go-to areas, intended to accelerate licencing, are under discussion. Here we discuss the challenges and possible solutions to the on-time implementation of REPowerEU in Mediterranean countries. The fast-shifting context, particularly the identification of Go-to areas, fail to reveal a troubling regional development conflict: wind resource and natural values overlap to a great extent. Greece and Portugal share many common characteristics: a) similar complex topography, b) an important network of Protected Areas (PAs) covering a considerable portion of the terrestrial area of the counties, c) up to 30% of wind turbines and installed capacity are inside Protected Areas (PA). The latter is not surprising since 40% of "good wind potential" fall inside PA and other environmentally sensitive areas for birds and bats, demonstrating the relevance of those territories. Constraints to development can be even larger when considering expansion, repowering, accounting for power grid layout, and existing connection points. Regarding biodiversity conflicting with wind energy development, we estimated that cumulative effects of collisions on birds do not significantly differ between wind turbines installed inside and outside PA. Also, we found no significant differences in most affected bird assemblages, suggesting that there is no reason to exclude developments based on contrasting mortality levels. We argue that even simplified licensing processes should shift the focus on avoidance and enforce strong baseline studies and project mitigation strategies, particularly in the context of high wind-biodiversity overlap. The Mediterranean region faces unique challenges in balancing wind energy development with biodiversity conservation objectives and mitigation strategies that prioritize biodiversity conservation should be the focus of wind energy development in the region. Such an approach would be beneficial to achieve 2030 targets.

Key words: REPowerEU, go-to area, licensing, Protected Areas, cumulative effects

HIGH LEVEL RISK ASSESSMENT & ITS USE IN MARINE SPATIAL PLANNING AND DECISION MAKING.

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Typically marine spatial planning involves combining shapefiles of key constraints data together and potentially applying a weighting to some datasets. The results of which are often subject to the agreement of weightings which may or may not work in the favour of the environment and are thus often the subject of challenge and much debate. Thus consensus is traditionally difficult across the different parties, often with no preferred solution identified. From an environmental perspective it is often simply designated site footprints that are used. This does not account for the fact that not all features and therefore sites are equally sensitivity to development nor does it account for the fact that many features are mobile and can be impacted outside of the footprint area. These can mean that conflicting areas of low sensitivity maybe over estimated as a risk or highly sensitive area are underestimated when weightings are applied to the whole layer. NIRAS has developed a high-level risk assessment method which can be used to create risk-based layers, which consider the mobile nature of features and the differing sensitivities within designated sites, to create risk based layers which can be incorporated into marine spatial planning. Therefore, enabling better considered of the environmental risk when identifying areas of offshore wind development. The NIRAS method; referred to as the HRA risk method, was originally developed for assessing uncertainty at plan level, but has been adapted for use in spatial planning when development areas are unknow. It is undertaken within GIS using a MCA approach and considers a number of criteria including the sensitivities of features to offshore wind farm development, feature density and distribution, sites condition and other pressures, to determine an overall risk score. This method has been applied at a UK scale. The resulting heat maps highlight the areas of higher risk for each key feature group (e.g. breeding birds, marine mammals, habitats). The criteria have been extended a step further to account for potential mitigation that might be available. This enables the end user to distinguish between areas of higher risk, but mitigation is available and readily applied, and areas of higher risk where little or no mitigation exists or is difficult. This allows a further dimension to decision making when weighing up this layer with other spatial planning criteria to define the extent of OWF areas.
Key words: risk assessment, uncertainty, marine spatial planning, offshore wind

OFFSHORE AND ONSHORE MAPS OF BIRD SENSITIVITY IN RELATION TO WIND ENERGY DEVELOPMENT FOR TWO EUROPEAN COUNTRIES

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The European Commission's REPowerEU plan to make Europe independent from Russian fossil fuels before 2030 includes ambitious goals on accelerating the growth of renewable energy. These include requirements for Member States to identify go-to areas for renewables such as wind and solar. To identify go-to areas, it will be necessary to accurately assess the potential ecological risks posed by large scale renewable energy expansion. The creation of avian sensitivity maps is therefore an essential precursor to the identification of go-to areas. Working with its national partners, BirdLife International have created detailed avian sensitivity maps for both on- and offshore wind development in Italy and Poland. It is hoped that these will not just aid bird-safe wind energy expansion in these two countries, but also create a robust and replicable model for mapping avian sensitivity that can be emulated throughout the European Union. Avian species sensitivity indices for on- and offshore wind in Italy and Poland were created using a modified version of the index developed by Certain et al., 2015. The three main impacts of on- and offshore wind energy on birds are collision, displacement, and habitat loss. In creating species sensitivity indices for on- and offshore wind, separate metrics were created to capture collision and displacement susceptibility. Additional metrics relating to conservation status, annual adult survival, and % of European population present in each country were included to capture the population implications of these impacts for the species. To incorporate the geographic distribution of landbird species, several sources of information were used to produce accurate maps for each species. Terrestrial features of biodiversity value were integrated into the assessment using landcover and land use data, Important Bird Areas (IBAs) and Protected Areas (Natura 2000), whilst at sea, marine features were integrated using IBAs, Protected Areas and seabird colonies (buffered to seabird foraging radii). The project resulted in a series of high-resolution maps depicting avian sensitivity in relation to on- and offshore wind resource in Italy and Poland. These maps provide an important resource for ensuring nature-safe wind energy expansion in Italy and Poland. In addition, they demonstrate a robust and replicable model that could be applied to all countries in the European Union. It is hoped that this exercise will be regarded as a necessary precursor to any large-scale wind energy deployment in Europe and a vital component of future go–to area identification.

Key words: Sensitivity mapping, wind energy, birds

COMPARATIVE ANALYSIS ON BEHAVIORAL RESPONSES FOR PRIORITY MSBS WHILE CROSSING WIND FARMS THROUGHOUT PRE- AND POST-CONSTRUCTION PHASE IN GULF OF SUEZ IN EGYPT

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To begin with, the Arab Republic of Egypt has developed an ambitious plan to increase the contribution of renewable energy to 42.5% of the electricity that will be generated by the year 2035, in which mostly wind power plants around 3 GW are foreseen to be constructed in the Gulf of Suez (GoS) due to wind characteristics in the area. Ras Ghareb Wind Energy RGWE 262.5 MW and West Bakr Wind Farm 250 MW are already constructed and operated at GoS since 2019 and 2021 respectively. The area where these wind farms were built to generate clean energy are overflown by hundreds of thousands of MSBs during spring and autumn bird migration periods so the bird fatalities could be posed by colliding MSBs with the wind turbines' blades. The main objectives of this presentation are to showcase of comparative analysis (spatiotemporally) from autumn 2019 to spring 2023 on magnitude and phenology of MSBs migration, avoidance behavior and shutdown operations for White Stork, Great White Pelican, European Honey Buzzard, Steppe Eagle, Levant Sparrowhawk, Egyptian Vulture, Greater Spotted Eagle, Eastern Imperial Eagle, Pallid Harrier, Black Kite, Common Crane, and Black Stork.

Key words: Turbine-Bird Interactions, Shutdown Operations, Deemed energy

MILANEOL – STUDYING THE RED KITE MORTALITY BY COLLISION WITH WIND TURBINES IN BELGIUM.

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The Red Kite (Milvus milvus) is the largest bird of prey in Belgium. The Belgian population is very important, and it represents a source for neighboring countries populations and the species expansion to the North. This emblematic species benefits from human activities and is therefore sensitive to them. One of the concerns regarding the Red Kite is the controversial wind farms environment, as this bird is known for being particularly sensitive to collision risks. Numerous studies are trying to assess the impact of wind farms on this species, but the subject is complex and includes many local factors. Our study aims to assess the impact of the Red Kite mortality by collision with wind turbine on its Belgian population. The MILANEOL project (a collaboration between University of Liège, CSD Ingénieurs and Natagora) wants to approach the topic broadly through three different parts: 1. Measure mortality via a systematic search for carcasses on the sites of two wind farms in Wallonia (Belgium), 2. Infer the viability of the population based on mortality data and various growth scenarios in a statistical framework, 3. From an ethics standpoint, study what an acceptable mortality is to justify a good conservation status, through interviews with various actors in the field. Our preliminary results, principally based on the cadaver search, on the discussions with local experts and on results from other projects, suggest that collisions with wind turbines have little impact on the Belgian population of Red Kite.

Key words: Red Kite, wind farms, collision, bird of prey, Belgium

DO AVOIDANCE/ATTRACTION RESPONSES OF KITTIWAKES FROM THE SAME COLONY VARY BETWEEN DIFFERENT WIND FARMS?

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Collision risk modelling (CRM) is a major part of ornithological environmental impact assessments when estimating the potential effects of a new offshore wind farm (OWF) development. Outputs of such models are sensitive to input parameters, including avoidance rate; an estimate of the proportion of birds which actively avoid collision (Band 2012). Recent studies have used tracking data to compare observed versus expected values of presence within defined areas around turbines and wind farm perimeters (Schaub et al. 2019, Johnston et al. 2022) in attempt to determine responses, with the ability to represent both avoidance and attraction ("Avoidance/Attraction Index" or AAI). Such empirically based knowledge may help to increase confidence in CRMs and further understanding of behavioural responses to OWFs in general. We used tracking (GPS) data to quantify the AAI of black-legged kittiwakes (Rissa tridactyla). A species with widespread declines in population (Birdlife International, 2019) and at risk of collision with wind farm turbines (Furness et al. 2013, Cook et al. 2014). There are three relatively small wind farms (5, 6, and 11 turbines) within the study colony's (Whinnyfold) home range during the breeding season. This provided a unique opportunity to detect potential differences in responses to different wind farms. This was conducted on two spatial scales; (i) "macro-response" which compared 1 km buffer zones extending to 4 km from wind farm boundaries, and (ii) "meso-response" to look at responses on a sub-kilometre (0-400 m) scale which can provide insight into responses to individual turbines. Results indicate attraction to the wind farm boundary within 0-1 km, with responses ranging from no attraction to avoidance at 1-4 km away. This pattern was not significant when the whole dataset was analysed for all wind farms combined but was significant for two of three OWFs when analysed separately. The response at meso-scale indicated significant avoidance of individual turbines in the 0-80 m region. Our study shows the complex avoidance response of kittiwakes to OWFs, with some similarities to responses seen in other gull species. It highlights the importance of inspecting responses at different scales, having implications for collision risk modelling, where one input parameter may be too simplified to capture such a response effectively.

Key words: Avoidance behaviour, collision risk modelling, black-legged kittiwake

BASIN STUDY ON ACOUSTIC RESPONSIVENESS IN WILD-CAUGHT HERRING FOR EXPLORATION OF DETERRENT POTENTIAL

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Sounds are an important cue for marine animals. As anthropogenic sound sources increasingly contribute to the underwater soundscape, this can negatively impact these marine animals, including fish. Pile driving during the construction of offshore wind farms and detonation of ordinance create high-amplitude, impulsive sound, which can be harmful to nearby fish. However, sound can also be used as a mitigation measure by means of acoustic deterrent devices (ADDs). ADDs play back a selection of sounds with the intention of keeping animals away from a potentially dangerous site. Previous studies have explored the efficacy of several sound stimuli in deterring marine mammals and in guiding freshwater fish. However, we still have little insight into what type of sounds would be most efficient to deter marine fish. In a few studies in captive conditions, rapid pulse trains and broad-band sounds have been shown to elicit a behavioural response in marine, demersal fish species. In this study, we played back a set of 8 pulse train sound stimuli, varying in amplitude and interval temporal pattern, in an indoor basin, to test for their response triggering potential in Atlantic herring (Clupea harengus). We recorded behaviour using underwater cameras. The setup allowed for 3D-position tracking using dedicated software. We could then automatically score behaviour, as well as potential habituation. We saw distinct behavioural responses when fish were exposed to sound, compared to the ambient control conditions. Preliminary results suggest that interval temporal pattern and amplitude are important acoustic parameters to take into account when designing effective ADDs. We have to be cautious with drawing conclusions, as data processing is ongoing, but it seems that fish reacted stronger to fade-out stimuli compared to fade-in or constant amplitude.

Key words: fish behaviour, acoustic deterrence, Atlantic herring, indoor study

PRESENCE OF LARGE CARNIVORES IN THE IMPACT AREA OF WIND POWER PLANTS DURING OPERATION IN CROATIA

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Large carnivores play crucial ecological roles in maintaining balanced ecosystems. However, their interactions with human infrastructure, such as wind power plants, are poorly studied and understood. With the increasing global demand for renewable energy, wind power plants have proliferated, leading to potential conflicts, challenges and risks associated with large carnivores. These include habitat fragmentation, direct or indirect loss of habitats, acoustic and visual disturbance, and increased human-wildlife conflicts. Additionally, the presence of wind power plants may disrupt their hunting patterns, movement corridors and influence their reproduction success which can have cascading effects on ecosystem dynamics. Understanding how large carnivores perceive, interact with, and adapt to human infrastructure, specifically wind power plants and their associated infrastructure, is essential for effective conservation and streamlining management efforts. Part of our independent research on large carnivores in Croatia, have confirm their presence in the impact area of the wind power plants during operation phase. Field results from camera trapping and transect tracking show evidence of large carnivores using the habitats for maintaining their general ecological needs including movement and reproduction, beside the effects of various impacts. This work tends to present the occurrence of large carnivores in the area of wind power plants during operation (in Croatia) as their ability to adapt, which is crucial for the sustainable coexistence of large carnivores and renewable energy infrastructure. Conservation and management strategies, such as site selection, wildlife-friendly design, and mitigation measures, should be informed by scientific research to minimize negative impacts on large carnivores and their ecosystems.

Key words: large carnivores, presence, wind power plants during operation

PELAGIC FISH PRESENCE AND BEHAVIOUR DURING PILE DRIVING IN TWO WINDFARMS

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Offshore windfarms are typically constructed by (impact) piling of monopiles into the sediment. Piling generates high levels of impulse sound which may impact marine life including fish. At close range of piling, it can lead to physical damage and hearing damage. Further away, piling may deter fish or change their physiology and behaviour. Not much is known on the consequences for pelagic fish as they have a very large home range and are therefore hard to track using acoustic tags. We used four bottom-moored monitoring frames with echosounders to monitor over swimming fish. We monitored sound levels and fish presence and behaviour during piling of 30 unique monopiles in two different windfarms in The Netherlands. Using the four frames, this resulted in acoustic and fish data at > 100 distances between ~ 0.3 and 9.7 km from the piling. We will be able to present the final results in September, but preliminary results suggests that piling sound could have induced TTS in fish up to a few kilometres from piling. We did not find clear changes in the amount of fish present, depth distribution, or swimming direction during piling. However, it seems that fish display more directional swimming (with half of the data analysed), potentially indicating a change in activity.

Key words: Fish, piling, behaviour, offshore windfarms

NAVIGATING THROUGH A MAZE: BEHAVIORAL RESPONSES OF THREE GULL SPECIES TO ONSHORE WIND TURBINES AT THE NORTH SEA COAST DURING THE BREEDING SEASON

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Expanding wind energy generation is essential to accelerate the renewable energy transition and reduce dependence on fossil fuels. At the same time, this expansion can have adverse effects on wildlife and especially bird populations, resulting in a green-green dilemma between mitigating climate change and protecting biodiversity. This may be particularly evident in coastal regions, key areas for both wind energy production as well as seabird populations. In addition to the risk of fatal collisions with wind turbine installations, other indirect consequences include displacement and barrier effects that may lead to habitat loss, resource exclusion and increased energetic expenditures. The extent and severity of these effects on birds are highly dependent on various interrelated factors, including their behavioral responses. It is therefore essential to gain insights into how different bird species react to the presence of wind turbines and to what extent their movement patterns may be affected through attraction or avoidance behavior. The aim of this study is to address this dilemma by investigating potential impacts of onshore wind turbines on the movement patterns of three seabird species during the breeding season: Lesser Black-backed Gulls (Larus fuscus), Herring Gulls (Larus argentatus) and Common Gulls (Larus canus). The study area is located along the German and Danish North Sea Coast, a coastal landscape characterized by a high number and density of wind turbines. Using high-resolution GPS tracking data, the species' behavioral responses to onshore wind turbines were investigated at a meso-scale by means of three different analysis techniques based on an integrated step selection model (iSSM). Results revealed a pattern of avoidance within the immediate surroundings of the turbine towers for all three species, but identified differences in both the extent and intensity of their reactions to the turbines. Recorded responses were strongest for the GPS-tagged Herring Gulls, while comparably weak effects were observed in case of Common Gulls and moderate but inconsistent patterns for Lesser Black-backed Gulls, measured by the relative intensity of use at several distances to the turbine towers. These findings provide important insights into the behavioral responses of birds to onshore wind turbines, essential to inform collision risk models and investigate displacement and barrier effects in future research. Furthermore, it emphasizes the importance of considering species-specific movement characteristics in assessing direct and indirect effects of wind turbines on individuals and bird populations to minimize conflicts between renewable energy and wildlife conservation.

Key words: GPS telemetry, seabirds, onshore wind turbines, behavioral responses, North Sea Coast

EFFECTS OF VIBRO PILING AND SHIP TRAFFIC ON THE ABUNDANCE AND BEHAVIOR OF HARBOR PORPOISE (PHOCOENA PHOCOENA)

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Effects of Vibro Piling and ship traffic on the abundance and behavior of harbor porpoise (Phocoena phocoena) The construction of offshore wind farms is accompanied by considerable noise emissions during pile driving. Several studies demonstrate a clear avoidance behavior of harbor porpoises (Phocoena phocoena) over a quite extended area around construction sites, due to underwater noise. High noise levels can lead to temporal (TTS) or permanent threshold shift (PTS) in their hearing abilities, which affects their behavior and survival. During the research project "VISSKA" a new form of pile driving (Vibro Piling) was used during the construction of the offshore windfarm KASKASI II in the German North Sea. By using Vibro Piling a reduction in noise emissions during construction can be achieved, making it a potential future technology to decrease impacts on marine live. Our study has a closer look at the harbor porpoise abundance and behavior during Vibro Piling activity and compares it to harbor porpoise abundance and behavior during pile driving. Further, it has a closer look at the ship traffic in course of the construction as well as usual ship traffic, i. e. cargo traffic, in close proximity to the construction site (5 km radius). Our study analyzes if the distance and size of the ship traffic led to different results in abundance and behavior of harbor porpoise. The abundance and behavior of harbor porpoises were studied using passive acoustic monitoring (PAM) and digital aerial surveys, with the aim of assessing the effects of 1) noise emissions caused by Vibro Piling during construction, and 2) construction-related ship traffic on harbor porpoise abundance. Within a study area of 1,906 km^2, data from automatic identification systems of ships (AIS) were combined with the data of 5 digital aerial surveys (HiDef) as well as 17 PAM stations (C-PODs). Aerial surveys are used to giving information on the presence of harbor porpoises on a high spatial scale, C-PODs recorded porpoise echolocation clicks and thus gave information on the presence of these animals on a high temporal resolution. Our study, carried out in a harbor porpoise high-density area, shows that the effects of Vibro Piling on harbor porpoise detection rates were less distinct than those of impulsive piling and ship traffic. This knowledge will help to develop efficient mitigation measures further reducing the disturbance of harbor porpoises during future constructions of offshore wind farms. VISSKA funding reference number (03EE3043B)

Key words: Vibro Piling, ship traffic, harbor porpoise, C-POD, aerial survey

BEHAVIOUR AND HABITAT USE OF BLACK-LEGGED KITTIWAKES (RISSA TRIDACTYLA) IN RESPONSE TO OFFSHORE WIND FARMS IN THE GERMAN NORTH SEA

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Many seabird species have been observed to react intensively to the existence of offshore wind farms (OWFs) in their foraging habitats. Against the background of a massive expansion, planned for OWFs in the German North Sea, we studied the response of black-legged kittiwakes (Rissa tridactyla) to OWFs. As a pelagic surface feeder, this seabird species is dependent on prey availability in the upper water layers. This dependence and its widespread abundance in the northern hemisphere make the black-legged kittiwake a suitable indicator species for environmental changes. 33 individuals were tagged from 2016 to 2021 in their breeding colony on Helgoland, Germany, southern North Sea. The majority of the kittiwakes (77 %, n= 25) predominantly avoided the OWFs. However, 23 % (n= 8) of the individuals often entered the OWFs. Based on the respective utilization distribution, attracted individuals used the OWFs and the immediate surroundings intensively while foraging and resting. When travelling between foraging and resting grounds and the colony, most individuals used areas outside the OWFs intensively. There was no strong difference in behaviour between female and male kittiwakes. When in OWFs, most kittiwakes chose distances of 125 – 600 m to the turbines. Further, an integrated step selection model (iSSM) confirmed an individual difference in attraction and avoidance response towards OWFs. It is planned to further improve this model, by incorporating additional environmental variables, e.g., proxies for prey availability. The findings are relevant for future risk assessments, modelling and planning of future wind farms, particularly those located near breeding colonies. Although an extension of offshore wind farms is considered desirable and needed, enough undisturbed foraging habitat for seabirds needs to be secured.

Key words: individual behaviour, Rissa tridactyla, offshore wind farm, wildlife telemetry

PRE- AND POST CONSTRUCTION MONITORING OF FOREST GROUSE LEK SITES IN A WIND FARM IN NORWAY

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The current knowledge about how susceptible different bird species are to collision with wind turbine generators (WTGs) is to some extent improving, but the knowledge about how they may disturb and displace birds is still very scarce. The black grouse and the capercaillie are two forest grouse species that occur widely in the northern part of Scandinavia. Both species engage in lek mating, with males gathering in competitive displays in display grounds (lek sites). These areas are very important for local populations, and they can remain in use for decades. It is widely accepted that both species are very vulnerable to human disturbance during the lek, and sudden events like loud noises or erratic movement can easily flush the lek sites. This has raised worry that wind farms, with their affiliated infrastructure and human activity, can negatively impact these lek sites. We have observed how birds on several lek sites from these two species appear to have responded to the establishment of a wind farm in southeastern Norway. Odal wind farm was constructed in 2020 with 34 WTGs and a total installed effect of 160 MW. The wind farm is situated in large and relatively intact coniferous forest areas where the black grouse and the capercaillie occur, with numerous lek sites known in close vicinity. As a part of the concession agreement, the Norwegian energy authority (NVE) demanded that monitoring should be conducted in a selection of lek sites within a relevant distance to the wind farm, pre-and post-construction. Norconsult has conducted these monitoring surveys, which took place in 2015 and 2023. Monitoring included outlining the lek sites and estimating the number of males using them. The data from pre and post-construction was then compared. Our limited data showed that the black grouse lek sites were still in use post-construction. For the capercaillie, the lek sites appeared to have been slightly displaced or moved away from the WTG's, but still remaining in the landscape, and we found signs the lek sites are still used for winter feeding purposes. This implies that even if both species are susceptible to collision with WTG they are not necessarily showing any strong displacement response. Therefore, the management authorities should consider mitigation measures to reduce the risk of collision in areas where black grouse and capercaillie occur and/or engage in lek mating.

Key words: Forest grouse, displacement, pre-/post-construction monitoring

VISITATION PATTERNS AND HABITAT USE OF FISH IN A CONTEXT OF OFFSHORE WIND ENERGY DEVELOPMENT

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In France, offshore wind energy development is rapidly expending with over 13 projects of offshore windfarms (OWF) currently in progress. OWFs can act as artificial reefs for certain fish communities with species exhibiting high residency patterns for these new habitats. In addition, underwater power cables within OWFs generate electromagnetic fields that can affect the behaviour of electro- and magneto-sensitive species (e.g. sharks and rays). Considering the ecological functions and socio-economic importance of fish communities, these effects need to be assessed through comprehensive and long-term monitoring. Currently, empirical evidence is sparse as the sampling design of traditional surveys used in OWF regulatory impact assessment is not usually sufficient or adapted to detect and quantify these effects. The collaborative FISHOWF project uses acoustic telemetry to identify how mobile fish species use and connect different habitats across OWF development areas in the Channel, Atlantic and Mediterranean sea. This project relies on dedicated receiver arrays deployed within OWF, combined with the region-wide acoustic telemetry networks FISHINTEL (Channel), CONNECT-MED & RESMED (Mediterranean) to monitor occupancy patterns and movements of over 400 fish/crustaceans (including sea bass, pollack, lobster, sharks and rays). Here we will present 1) the specific goals of the FISHOWF project, 2) the challenges encountered for the deployment of our acoustic arrays within OWF and, 3) our preliminary results on fish occupancy and movement patterns within OWF (in construction and operational). Results will be used to better assess the effect of habitat modifications induced by OWF implantation from the seafloor to the surface.

Key words: Offshore wind energy, Acoustic telemetry, Habitat use, Movement patterns

A RADAR AND ESAS STUDY OF SEABIRD ACTIVITY ON A FLOATING OFFSHORE WIND POWER PROJECT

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Offshore wind energy is rapidly expanding with significant impact on seabirds. Assessing those impacts requires methods to comprehensively survey seabird activity in the marine environment capturing both the annual and monthly variation as well as the circadian. We compared the results from seabird monitoring programs conducted at the Windfloat Atlantic II offshore floating wind power project where radar surveys and boat based ESAS surveys were conducted simultaneously on the three turbines (8.4 MW each), located 18km from the coast in offshore waters of northwest Portugal. The two datasets were collected between November 2020 and June 2022. The radar data was obtained on a long-range Birdtrack S-band radar system operating on surveillance mode at a range of 4,5 km which delivered continuous data on bird activity, flight direction, flight speed and behaviour. The ESAS survey data was obtained from six boat campaigns each year which delivered data on bird activity, species, number of individuals, flight direction, flight height and behaviour. Both Birdtrack radar and ESAS data showed higher seabird activity during pre- and post-nuptial migration and during winter. The observed flight directions were coherent with phenology of the species occurring in the region where most bird targets headed southwards during autumn and winter but headed mostly northwards during spring. Moreover, most radar targets were recorded during the day in spring, summer and winter, peaking in the morning and late afternoon. Noteworthy, the radar data shows an increment in bird activity at night (64%) during autumn most likely associated with nocturnal seabird migration. This information in unobtainable using standard visual monitoring methods, such as ESAS, and represent a novel aspect of seabird activity monitoring at offshore wind farms. Nocturnal activity of seabirds is known, in particular during migration, thus posing vulnerability of seabirds to collision with offshore turbines. The array of species likely to be active at night during migration in the region include gulls, terns, norther gannet and shearwaters, including the Critically Endangered Balearic Shearwater. Understating the circadian movement patterns during the 24h-period is crucial to carefully evaluate, assess and prevent impacts on seabirds. Monitoring seabirds with Birdtrack radar technology allowed further to characterize seabird activity during the night revealing an important nocturnal use of the area during migration.

Key words: Seabird activity, Floating wind power project, Birdtrack, Radar survey, ESAS survey

RADAR ESTIMATES FOR MODEL PARAMETERS OF COLLISION RISK AROUND WIND TURBINES IN THE CHILEAN PATAGONIA

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Transitioning our energy economy away from fossil fuel dependence towards one based on renewable and alternative forms of energy requires novel solutions for energy storage, in which the role of hydrogen has promising potential. Very large wind power projects are an increasingly used as source of renewable energy to feed the energy intensive plants for producing green hydrogen and derived fuels, such as green ammonia. But there are concerns of their potential effects on wildlife, particularly on birds. As part of the Total Eren H2 Magallanes Complex, the 10000 MW H2M wind farm is the world's largest onshore wind power project covering 73.785 ha of Chilean Patagonian grasslands and is included in the IBA (Important Bird Area) of Estancia San Gregorio and in the EBA (Endemic Bird Area) 062 – Southern Patagonia, in the Magellan region of southern Chile, home to the main breeding grounds for the Ruddy-headed Goose Chloephaga rubidiceps, a species classified as Endangered. To address this issue, a comprehensive quantitative radar study was devised to assess the bird collision risk of the Phase 1 (5 GW) of H2M wind power project with focus on the species Ruddy-headed Goose and to design appropriate mitigation actions. The study was conducted over a 12 months period and will provide a detailed understanding of how these species interact with wind turbines. A dual setup comprising of a X-band Birdtrack radar operating in scanning/surveillance and counting modes (horizontal and vertical radar operation, respectively) was used to measure the flight patterns of birds in the study area. This technological approach focused on acquiring empirical and high resolution data for collision risk modelling, including in situ system calibration with bird observers. The use of Birdtrack radar system aimd to increase the accuracy and reliability of the data collected, allowing for a more comprehensive assessment of the behavioural responses of the target species. To calculate species specific risk of collision metrics the model parameters were obtained from x-band radar measured empirical data such as flight height, flight speed, flight direction, mean traffic rates and population densities at two vertical mode ranges (0,4 km and 1,5km) and on horizontal mode range (4,5 km). The methodology used to estimate the collision risks and analyse behavioural responses will provide important insights into species-specific responses and behaviour of the target species at the wind farm to inform appropriate mitigation actions.

Key words: Radar, Collision Risk Model, Wind turbine, Endangerd species, Ruddy-headed Goose

EUROPEAN NIGHTJAR AND WIND TURBINE GENERATORS (WTG) - MOVEMENT AND DISPLAY RESPONSES TO TURBINE PRESENCE AND OPERATION.

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In this study, we use movement data from two European wind farm sites (Sweden and U.K.) to investigate the observed behaviour of nightjar around WTG in various weather conditions. We hypothesised that nightjar would avoid foraging and display in close proximity to turbines during operation (wind speed >5m/s) and would select foraging habitat based on prevailing weather conditions (wind direction and speed). In order to test these hypotheses we used gps tag tracking data from 18 individuals, alongside site specific habitat data and weather data from WTG. Tracking data was classified into behaviour classes based on velocity and turn angle using embc. Resource selection functions were then used to investigate the probability of observing foraging and display behaviours using distance to WTG, habitat type, wind speed and temperature as covariates. We discuss the results of this analysis and it's implications for wind farm layout and development in important nightjar areas.

Key words: European nightjar, movement, GPS tracking

FLAT OYSTER RESTORATION IN THE DUTCH NORTH SEA: COMPARISON OF FIVE PILOT PROJECTS (2018-2021)

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The European flat oyster (Ostrea edulis) is a biogenic reef former and one of the focal species in nature inclusive building in offshore windfarms in The Netherlands. Oyster reefs offer habitat to many other hard substrate benthic and fish species, and provide ecosystem functions such as shelter and feeding grounds. They have disappeared from the Dutch North Sea in the early 1900s due to overfishing and diseases, but are now subject of nature restoration under the Dutch Marine Strategy. MATERIALS AND METHODS Since 2018, European flat oysters pilot restoration project have started at several at suitable locations in offshore windfarms and nearshore, protected from bottom trawling. We compared five pilot projects which used adult oysters sourced from Ireland, Norway and the Netherlands. The restoration projects all differed in their setup to try-out various monitoring strategies and were located in near-shore and off-shore (offshore wind) environments. Adults oysters were placed in baskets on heavy racks or in light weight cages at the seafloor and taken out months later for measurements on shell width, condition and potential presence of the parasite Bonamia. Larvae were sampled in summer by filtering 200 l of seawater/sample from near the oyster bed and counted under the microscope. Environmental data were obtained from Copernicus. AIM The aim was to compare the performance of the deployed oysters between projects and to provide recommendations for future projects. RESULTS We found that both foreign sourced flat oyster populations (Ireland and Norway in nearshore and offshore areas) and local oysters (in nearshore area) perform well in the Dutch North Sea. Oysters were able to grow and reproduce (larvae present). We found that growth rate was related to average water temperature, but not to other environmental factors such as salinity, Chla, pH and O2. Furthermore, oysters were Bonamia-free at the start of the pilots and none of the oysters tested was Bonamia positive afterwards, indicating that the Dutch North Sea is still Bonamia-free. CONCLUSIONS Up to 2050 many new offshore farms will be constructed in the Dutch North Sea and a number of them will be suitable for oyster restoration. We conclude that local and foreign sourced oysters performed well at all locations. Based on the success and failure of the different monitoring techniques, we provide some recommendations on good practice for the future, including the use of standardized monitoring protocols. This will enable better inter-site comparisons in upcoming oyster restoration projects.

Key words: European flat oyster, Nature Inclusive Design, Offshore Wind

THE COMMON BUZZARD – A MODEL SPECIES FOR BIRD-WIND TURBINE INTERACTION: GPS/GSM DATA FROM KALIAKRA, NE BULGARIA

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The common buzzard (Buteo buteo) is a widespread bird of prey, typical for temperate zone of Europe, with large distribution and high number. Buzzards are often exposed to interaction with infrastructure related to wind power. We have compared three different evolutionary strategies in an area with operating wind turbines. For our study we selected comparable periods despite of the established different migratory strategies of this species revealed in our study. In last three years we tagged 8 common buzzards with GPS/GSM transmitters in order to evaluate variations in behavior of birds and potential mortality rate in an area with operational 114 wind turbines. For indication of potential changes in behavior in respect to wind turbines we have investigated flight activity, changes in flight direction and altitude of flight obtained by GPS/GSM from 8 tracked birds. Our results show that all tagged free-living common buzzards has experienced contacts with operational wind turbines. Over 200 fixes are located in radius of 20 m around a wind turbine. Over 2285 fixes are located in radius of 100 m around a wind turbine and 53 400 fixes are located in radius of 500 m around a wind turbine. None of the tagged birds died in collision with wind turbines, 3 were poisoned by rodent pesticides, one shot by poachers. Comparative analysis of two breeding seasons of the same individual in two consequent years allowed details of the behavior. In the first year nest was located in an area far from wind turbines while in the next season between two operational wind turbines. Observed changes in flight direction as well as in altitude of flight of the same individual was higher in the first year when the nest was located far away from wind turbines, and significantly lower when nest was in a shelterbelt between two operational turbines. The same bird demonstrated higher ODBA in the nesting period between the turbines. High variability of the ODBA was confirmed in all tracked buzzards between the years despite of the fixed ranges in all three years. Our analysis did not reveal any changes in flight altitude, number of changes in flight direction and ODBA of the model species in respect to wind turbines in the breeding range of the birds. On this basis, we can confirm that the wind turbines do not constitute material obstacle for normal life of the model bird species – the common buzzard.

Key words: behavior, GPS tracking, bird model species, collision rate,

CONTRASTING EFFECTS OF TWO LARGE WINDFARMS IN SCOTLAND ON COMMON SNIPE GALLINAGO GALLINAGO AND EURASIAN CURLEW NUMENIUS ARQUATA POPULATIONS

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Aims This study aimed to quantify whether the observed distribution of snipe and curlew registrations are influenced by proximity to wind turbines, and to compare populations during windfarm operation with the pre-construction baseline projected by national population trends and those predicted by Pearce-Higgins et al. (2009). Methods An impact-gradient study design was fitted to observed snipe and curlew registrations collected pre-construction and during operation at two windfarms (Black Law and Whitelee) to test for effects of displacement. Population trends during the operational phase were also compared to the pre-construction data projected forwards through time using both national trends and applying additional reductions using Pearce-Higgins et al. (2009). Results There was no evidence of displacement of either species in areas between 250m and 1000m from turbines, nor any evidence of displacement within 250m for either species at Whitelee. Conversely, at Black Law the registrations of both species within 250m of turbines were further from turbines than predicted by the random null model. There were no effects on population sizes of either species at Black Law, with curlew numbers during the operational phase equivalent to predictions using the national trend and snipe numbers were significantly higher than predicted. At Whitelee curlew numbers were equivalent to predictions using the national trend and significantly higher than the predictions using Pearce-Higgins et al. (2009). Conversely, snipe numbers were lower than predicted using the national trend and equivalent to predictions using Pearce-Higgins et al. (2009). Conclusion The effects of wind turbines on wader distribution and population size were limited in this study, with some contrasting results between sites suggesting that other variables may have a greater role in determining distribution and abundance.

Key words: Curlew, Snipe, displacement, waders

BEHAVIOURAL REACTIONS AND SPATIO-TEMPORAL MOVEMENT PATTERNS OF MIGRATORY BIRD SPECIES CONFRONTED WITH OFFSHORE WINDFARMS IN THE NORTH AND BALTIC SEAS

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The North and Baltic Seas are key areas for massive installations of offshore windfarms (OWFs) by EU member countries and the UK. While first estimates of collision risks and barrier effects have been provided for foraging seabirds, according data are notably lacking for migratory (non-offshore) species, but are essential to inform marine spatial planning. We therefore analysed individual-based movement data of three long-distance migratory bird species, i.e. the near threatened Eurasian curlew (Numenius arquata) as well as brent (Branta bernicla) and barnacle geese (B. leucopsis) to assess behavioural reactions and spatio-temporal movement patterns against the background of OWFs. For curlews we compiled an international dataset consisting of 259 migration tracks for 143 Global Positioning System-tagged Eurasian curlews from seven European countries recorded over 6 years, to assess individual response behaviors when approaching OWFs at two different spatial scales (i.e. up to 3.5 km and up to 30 km distance). Generalized additive mixed models revealed a significant small-scale increase in flight altitudes, which was strongest at 0–500 m from the OWF and which was more pronounced during autumn than during spring, due to higher proportions of time spent migrating at rotor level. Furthermore, four different small-scale integrated step selection models consistently detected horizontal avoidance responses in about 70% of approaching curlews, which was strongest at approximately 450 m from the OWFs. No distinct, large-scale avoidance effects were observed on the horizontal plane. Overall, 29% of the flight tracks crossed OWFs at least once during migration. Approximately 16% and 6% of the entire curlew population were estimated to be at increased risk during autumn and spring migration, respectively. In contrast to curlews, both geese species showed a distinct migration corridor and a very narrow time window for their offshore migration suggesting temporal turbine curtailments as possible mitigation measure. A high proportion of the geese migrated at turbine heights (i.e. around 90% of both species), while around 25% of migration time was spent on rotor heights. Our data clearly show strong small-scale avoidance responses in all three species, which are likely to reduce collision risk, but simultaneously highlight the substantial barrier effect of OWFs for migrating species. Although alterations in flight paths of long-distant migrants due to OWFs seem to be moderate with respect to the overall migration route, there is an urgent need to quantify the respective energetic costs, given the massive ongoing construction of OWFs in both sea areas.

Key words: Telemetry, long-distant migrant, collision risk

THE ROLE OF HABITAT AND PREY QUALITY IN MARINE MAMMAL RESPONSES TO DEVELOPING OFFSHORE WIND LANDSCAPES

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As top predators, harbour seals (Phoca vitulina) play a key role within marine ecosystems, having top-down effects on fish communities and the food web structure. With the increasing presence of offshore wind farms (OWF) in coastal waters, there is an urgent need to understand how these developments may impact these top predators and their interactions with surrounding ecosystems. Harbour seals have been shown to change their diving and movement behaviour in response to the installation of turbine foundations, but the nature and magnitude of behavioural responses showed marked variation both within- and between-individuals. At present, there is a paucity of data on how factors such as an individual seal's behavioural state (e.g. foraging or travelling), and the underlying habitat and prey quality, may modify these behavioural responses to OWF construction. Importantly, this lack of knowledge limits our understanding of the nature of the observed responses, and our ability to predict the future consequences of OWF developments in new areas. To address these knowledge gaps, this project is investigating the effects of different phases of OWF developments on prey quality, and on harbour seal diving behaviour, movements, energetics, and spatial distributions. The work presented here is part of a larger research project investigating interactions between OWFs and marine ecosystems: the Predators and Prey Around Renewable Energy Developments (PrePARED) project. Fish samples (n = 430, 16 species) collected off the east coast of Scotland during 2022 are being analysed using bomb calorimetry to determine prey quality, in terms of energetic content by species and size class. To date, 105 fish samples (11 species) have been processed, showing broad variations between species and size classes, with energy content values ranging from 3.7 to 9.0 kJ/g. These results represent the start of a planned three-year dataset on the energetic quality of fish. In addition, GPS tag data from wild seals in south-east England (n = 45) and north-east Scotland (n = 30) are being analysed to determine the influence of their behavioural state, habitat type, and prey quality and abundance, on seal behavioural responses to pile driving, with the aim of developing a series of context-specific dose-response relationships to pile driving sound. The findings from this project will improve our understanding of the underlying mechanisms driving seal responses to OWF developments and will aid in reducing uncertainty in the impact assessment process.

Key words: seals, prey, foraging, energetic content, offshore

REVIEW OF EVIDENCE TO SUPPORT OF GUILLEMOT (URIA AALGE) AND RAZORBILL (ALCA TORDA) DISPLACEMENT IN RELATION TO OFFSHORE WIND FARMS.

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APEM undertook an evidence-based review and meta-analysis of guillemot (Uria aalge) and razorbill (Alca torda), to determine auk displacement rates for use in Environmental Impact Assessments and Habitat Regulations Assessment (HRA) reporting. Evidence was collated from multiple sources, including 21 offshore wind farm (OWF) post-consent monitoring reports, published research papers and online study reports that provide data on displacement effects associated with auk species. Displacement effects varied from strong attraction to strong avoidance, however, OWFs could be separated into two groups: 1) OWFs with inferred avoidance or displacement rates higher than 50%, 2) OWFs with no significant displacement effect or suggested weak avoidance of <25% displacement. Review of the analysis methods and data inputs used in each of the studies identified that OWFs reporting high displacement rates were associated with low count data which included high zero counts within the data set. The use of statistical methods that are unable to manage such zero-inflated data sets may lead to displacement rates that are misleading. An independent re-analysis of data from OWFs using Integrated Nested Laplace Approximations (INLA), a statistical method that can incorporate the issues mentioned above, demonstrated no significant effect for two OWFs which previously reported displacement and the other OWFs reporting high displacement effects could not be re-analysed using INLA, with the recommendation that their displacement rates should be treated with caution. The compilation of study data and associated OWF design metrics from this study provided the opportunity to examine variables associated with displacement effects. Twelve variables were tested for differences in pairwise comparisons between OWFs grouped according to whether a displacement effect was shown or inferred and those shown to have no significant displacement effect. Four variables were shown to be significantly different between groups inferring an association with displacement effect, these variables were: auk abundance, density (total windswept area as a percentage of the array footprint), distance from shore and geographical region. The review highlights that other factors may also be associated with the magnitude of displacement effects and OWFs with similar attributes are likely to demonstrate similar displacement effects. Therefore, by considering OWF site attributes the displacement rate can be refined from the broad range reported across all OWFs and tailored to an individual development based on similar attributes known to effect displacement rate and thereby removing a high level of uncertainty.

Key words: Auks, Displacement, offshore wind farms

REVIEW OF THE POTENTIAL IMPACT OF OWF LIGHTING EFFECTS ON ORNITHOLOGICAL RECEPTORS, WITH PARTICULAR REFERENCE TO MANX SHEARWATER (PUFFINUS PUFFINUS)

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APEM undertook an evidence-based review of OWF lighting effects on ornithological receptors, with particular reference to any consequences on Manx shearwater (Puffinus puffinus), for which the majority of the world population is located within UK waters in the breeding season. Birds may be attracted to or deterred by artificially illuminated structures in the offshore environment, such as oil and gas platforms or offshore wind farms (OWFs), during the hours of darkness or poor weather conditions which result in restricted visibility. Impact effects may be positive; providing opportunities for extended feeding periods, shelter and resting places or navigation aids for some migrating birds, or negative; causing change in course direction during migration and increased energy expenditure or displacement during nocturnal foraging. The majority of offshore evidence on lighting effects is compiled from studies from oil and gas platforms. However, OWFs are not as extensively lit or intensively lit, compared to oil and gas platforms which may also include gas flares, so this study reviewed the potential magnitude of such effects from OWFs. Predicting behavioural changes to artificial lighting also required consideration of species, age and season. Nocturnal flights at colonies were examined to understand Manx shearwater responses to different intensities, wavelengths and durations of light. This showed birds were more responsive to high intensity light, least responsive to red light and longer continuous light durations elicited stronger responses. This lower sensitivity to red light has been demonstrated at Bardsey lighthouse, which changed to a red flashing light in 2014 and resulted in a huge reduction in collisions of Manx shearwaters. Current literature and monitoring from existing OWFs currently provide insufficient evidence to suggest any potentially significant effects on Manx shearwater occur as a result of aviation and navigation lighting at OWFs. However, light-induced disorientation to the navigation lights on OWFs based on studies on attraction to lighthouses, buildings, offshore oil and gas platforms or other species' responses is contrary to evidence on Manx shearwater behaviour to red light or flashing lights. Therefore, the conclusion of the review was that based on current evidence the potential for Manx shearwaters to be attracted or disorientated by artificial light is predominantly in low ambient light and poor weather conditions in either adults approaching burrow sites or in fledglings on maiden flights, which means there is a lower risk to this species from OWFs.

Key words: Manxies, lighting, effects, OWFs

APPLICATIONS OF STRUCTURAL EQUATION MODELING (SEM) TO UNDERSTAND THE POTENTIAL CAUSES OF SEA TURTLE STRANDINGS IN TAIWAN

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Five of the seven marine turtle species are present in the coastal areas of Taiwan: the Chelonia mydas, Eretmochelys imbricata, Lepidochelys olivacea, Dermochelys coriacea, and Caretta caretta. Human activity, including fishery bycatch, coastal development, marine debris, global environmental change, and marine pollution, presents formidable risks to sea turtle populations. Furthermore, enthusiasm for offshore wind farms and other sources of sustainable energy is currently surging, as the widespread development and adoption of sustainable energy are critical to mitigating climate change and its effects. Offshore wind turbine can have potential impacts on sea turtles in several ways. These include (1) vessel collisions with turtles, such as collisions involving the working b oats of wind turbines; (2) underwater sounds resulting from wind turbine operation, including pile driving; and (3) local magnetic disturbances caused by cables, which can interfere with sea turtle migration. Therefore, determining which effects result from offshore wind turbines, other human activities, and/or environmental factors can be difficult. The current study quantitatively analyzed the impacts that numerous human disturbances and natural effects have on sea turtles, including the effects of offshore wind turbines. Using principal component analysis, this study identified four primary factors (i.e., potential variables) that drive environmental change in the coastal waters of Taiwan: “river-derived nutrients”, “phytoplankton photosynthesis”, “heavy metals”, and “seasonal variation”. We found that coastal areas of densely populated western regions were characterized by greater eutrophication and land-based pollution than coastal areas in the eastern, northern, and southern regions. Results from structural equation model indicated that areas with higher concentrations of heavy metals and fishing activities were influential factors associated with the number of stranded sea turtles. Nevertheless, no association of offshore wind turbines and the number of stranded sea turtles was identified in this study. Previous literature has reported that bycatch, net entanglement, and collisions with vessels can cause significant harm to sea turtles. Although we cannot confirm whether high concentrations of heavy metals are harmful to sea turtle health, other researchers have raised concerns about heavy metal pollution in sea turtle habitats. In our study, although no association was found between offshore wind turbines and turtle strandings, it should be noted that the offshore wind turbines examined in this study were not located in sea turtle hot spots or important migratory corridors. Therefore, future analyses investigating the impact of offshore wind turbines on sea turtle populations in important habitats should be conducted.

Key words: structural equation modeling, sea turtle, strandings, wind energy

SPATIAL AND TEMPORAL PATTERNS OF BAT FATALITIES AT ONSHORE WIND FARMS IN TAIWAN

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Wind power is among the fastest-growing renewable energy sources, and offers an alternative to fossil fuels in reducing greenhouse gas emissions. However, increasing evidence indicates that wind facilities cause widespread and significant bat fatalities. Previous studies mainly focused on temperate regions (i.e. Europe and North America), and little attention has been given to the tropics/subtropics, where wind power is also rapidly developing and bat diversity and abundance are high. The impacts of wind facilities on bats in Taiwan are largely unknown, despite the country's ambitious goal of reaching approximately eight times its current wind capacity installed by 2030. To address this knowledge gap, we conducted a bimonthly survey on bat fatalities at 233 onshore wind turbines across 16 wind farms located on the western coast of Taiwan between November 2018 and March 2021. We documented 233 bat carcasses, with 220 identified as eight species from two families (Vespertilionidae and Miniopteridae). Taking into account the carcass persistence, searcher efficiency, and the size of searching areas, we determined an average fatality of 338.4 (95% CI: 23.1-1066.0) bats/turbine/year, or 155.4 (95% CI: 10.6-489.2) bats/MW/year, which was well above the fatality rates reported from any other region of the world. The majority of the bat fatalities consisted of Pipistrellus abramus (43%), Eptesicus pachyomus horikawai (21%), and Nyctalus plancyi velutinus (15%). All of them are open- or edge-space foragers, and their congeners are generally more often reported than other genera from the wind farms in Europe. In addition, we also documented Vespertilio sinensis (n =1) and Myotis formosus flavus (n =2), listed as nationally endangered and vulnerable respectively on Taiwan's Red List. Bat fatalities varied among wind farms surveyed, with the highest along the coast in central Taiwan. Fatalities also exhibited a seasonal pattern with the highest in summer and early fall, and the lowest in winter. Our findings suggest that poor wind farm siting, coupled with high bat activity levels during long and warm summer nights, contributed to the high bat fatalities observed in Taiwan. This study represents the first assessment of bat fatalities in wind farms in the tropical/subtropical Asian region, highlighting an urgent need to evaluate and mitigate the impacts of wind facilities on bats in this area.
Key words: climate change, sustainable development, wildlife conservation, collision, GenEst

ASSESSING CUMULATIVE IMPACTS OF COLLISION RISK ON SEABIRDS CAUSED BY COMMERCIAL OFFSHORE WIND FARMS IN THE ENGLISH CHANNEL, NORTH SEA AND ATLANTIC COAST (BIRDRISK)

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Cumulative impact assessment is vital to understanding the population-level impacts of offshore wind farm developments on highly mobile seabird species that could encounter numerous renewable energy developments within their foraging or migratory ranges. As ranges also cross geopolitical boundaries, a complete picture will only be possible if an international approach is taken. BIRDRISK is a novel project assessing the cumulative impacts of seabird collision with commercial wind farms in the English Channel, North Sea and Atlantic coast. This project led by the French government comprises two parts, the first of which focuses on the firsts seven French offshore wind farms currently in various stages of development, construction or operation, and the second of which takes in 25 additional international projects. The twenty French water seabird species to be studied were selected according to criteria including distribution, conservation importance, and sensitivity to collision. The selection method is based on ranking or overclassification matrix and experts' judgments. Collision risk is assessed using the stochastic Collision Risk Model (sCRM) tool currently used as standard in the UK which uses data on bird densities, biometrics and behaviour alongside wind farm specifications to predict monthly collision risk with uncertainty capturing natural variation and uncertainty in input parameters. The required data on seabird distribution and wind farm specifications were gathered from developers. Bird data comprised a mixture of boat-based and visual aerial survey data collected over differing temporal periods and with different recording strategies. The aim was to ensure that site-specific data were used where possible in order to maximise the robustness of the assessment, presenting several challenges in terms of deriving appropriate inputs for the collision risk model. For example, the proportion of birds flying at collision risk height often couldn't be directly determined from the data so these were estimated from modelled site-specific flight height curves where possible, or alternatively derived from published generic flight height curves. An international approach to cumulative impact assessment is vital to achieve a full understanding of the impacts of offshore wind farm developments on seabirds. However, such an exercise will inevitably require combining disparate datasets that are collected according to different methodologies and guidance. We will present the challenges encountered during the process, the methods used to overcome these and recommendations for others doing similar studies, alongside key outcomes of the project so far.

Key words: seabirds, collision risk, cumulative assessment, offshore wind farm

UNDERSTANDING THE MAGNITUDE AND DRIVERS OF FORAGING ROUTE FIDELITY IN SEABIRDS IN THE AGE OF OFFSHORE RENEWABLES

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A key outstanding knowledge gap limiting current offshore wind assessments is the extent to which interactions between seabird populations and offshore renewable developments (ORDs) are driven by a limited number of individuals from a population interacting frequently with an ORD (large impacts on a small proportion of the population), versus many individuals interacting only occasionally with an ORD (small impacts on a large proportion of the population). This relates to 'turnover' of individuals in key locations within and around ORDs and is driven by the level of fidelity in foraging routes and locations within and across individuals. Quantifying the level of fidelity is therefore critical to estimating how ORDs may generate population-level impacts through their impacts on individual birds. Here we used nine years of GPS tracking data collected prior to the construction of ORDs in south-east Scotland, to understand the magnitude and timescales of fidelity in four seabird species (common guillemot, Atlantic puffin, razorbill, and black-legged kittiwake). We quantified both fidelity within and between breeding seasons, and estimated relationships between fidelity and both foraging behaviour and social context to identify behavioural processes that may underpin potential responses to ORDs. We found strong evidence for within-year fidelity in all species, indicating that birds exhibit foraging fidelity across the breeding season. All species also exhibited between-year fidelity, suggesting that fidelity also extends over longer timescales. We found that guillemots and razorbills showed higher fidelity between trips when their apparent foraging efficiency was higher, suggesting they adjust fidelity to their own foraging experience. We also found evidence that birds use social information when choosing foraging routes, particularly in puffins, where individuals were more similar in their trips when they overlapped at the colony or out at sea. Our results indicate the need to consider fidelity when upscaling observed changes in at-sea distribution of birds post construction (i.e., quantifying displacement rates) to any subsequent population-level demographic impacts. Our results also suggest that individuals may use personal and social information to alter the magnitude of fidelity, which may promote resilience in relation to ORDs, particularly if they are associated with changes in prey distributions.
Key words: seabird, fidelity, foraging, personal information, social information

INCREASING BIOLOGICAL REALISM IN INDIVIDUAL-BASED MODELS OF SEABIRDS TO PREDICT THE IMPACTS OF OFFSHORE WIND FARMS

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Quantifying the sub-lethal impacts of offshore renewable energy developments (ORDs), such as displacement and barrier effects, requires an understanding of the behavioural responses of individual birds to such developments, which result in changes to time-activity and energy budgets, and ultimately shapes changes in demographic processes of reproduction and survival. In the absence of detailed empirical observations of the individual responses of birds to ORDs and subsequent changes to demography, current impact assessments rely upon a range of predictive models for estimating demographic consequences of displacement and barrier effects in protected wildlife population. As part of the PrePARED research project (Predators and Prey Around Renewable Energy Developments, funded by OWEC in the UK), we are improving the biological realism of one such predictive tool, the individual-based model (IBM) 'SeabORD', to better capture behavioural mechanisms of foraging trips and flight patterns in a range of seabird species, and how these changes are linked to redistribution of seabird prey around operational ORDs. The PrePARED project will provide underpinning research to allow for significant advancements in the ability of predictive models to include biologically realistic predator-prey interactions through incorporating recently developed fine-scale prey distribution maps. The project will also deliver new methodologies for increasing the realism of foraging tracks for a range of seabird species. By analysing biologging data for five seabird species in the model (Atlantic puffin, common guillemot, razorbill, black-legged kittiwake and northern gannet) we show how it is possible to decompose foraging trips into different behaviours, and to identify key parameters for capturing the internal structure of trips. By using contemporary Bayesian methods, we can then generate more biologically plausible foraging trips for seabirds, including their response to environmental covariates and ORDs. We then implement these foraging tracks and responses within SeabORD to assess changes to daily energy expenditure to estimate adult mass change over the breeding season, and to link provisioning of chicks to breeding success. This will deliver a new tool capable of mechanistically capturing key prey and seabird responses to ORDs during the breeding season, reducing uncertainty in the magnitude of sub-lethal impacts in protected seabird populations, and leading to greater confidence in assessment methods. In this talk I will present an overview of our research within the PrePARED project. Given the wide scope of this topic, and potential adoption when it is complete, we believe it is of interest to science and industry alike.
Key words: Displacement, barrier effects, individual-based models, predator-prey interactions

IMPACTS OF OFFSHORE WINDFARMS ON DIFFERENT SEABIRD SPECIES

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Offshore wind farms (OWFs) are becoming a key factor in Europe´s green energy mix. However, these installations currently change the structure and appearance of marine habitats in a dramatic way. Seabirds are a species group that show various reactions to those new anthropogenic structures: some species avoid these areas and loose habitat; others get attracted and might thus have a higher risk for collisions. There are already various operating OWFs in the German North Sea and according comprehensive data that document the distribution and abundance of different seabird species under those impairments. These datasets comprise environmental impact studies, the German Marine Biodiversity Monitoring and scientific projects before and after construction of the OWFs. Additionally to the well-known effects on loons (Gavia spec.) which show an avoidance behaviour up to a distance of 12 km, we now analysed the reactions of six more seabird species of the German North Sea by modelling their distribution with Generalised Additive Models and analysing behavioural responses using a BACI (Before After Control Impact) approach. This poster will show the results of the distribution patterns as well as the avoidance- or attraction-effects for Common Guillemots (Uria aalge), Razorbills (Alca torda), Northern Gannets (Morus bassanus), Northern Fulmar (Fulmarus glacialis), Black-legged Kittiwake (Rissa tridactyla) and Lesser Black-backed Gulls (Larus fuscus). For Guillemots, Razorbills, Northern Gannets and Northern Fulmar we found significant avoidance behaviour. The distance from the OWFs to which avoidance was recorded differed among the species. Blacked-legged Kittiwake and Lesser Black-backed Gulls showed variable reactions depending on the season that reached from attraction to avoidance. The presented results clearly show that not only loons (Gavia spec.), but various seabird species are affected by OWFs in a negative way and thus should be considered in future marine spatial planning processes.
Key words: Offshore wind farms, Seabirds, avoidance, attraction, spatial planning

ORJIP OFFSHORE WIND - SUMMARY OF ONGOING PROJECT RESULTS

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The Offshore Renewable Joint Industry Programme (ORJIP) for Offshore Wind studies the impact of offshore wind farms in the marine environment, in order to reduce consenting risk for offshore wind farm developments and support increased capacity growth. ORJIP for Offshore Wind is a collaborative initiative that aims to:

• fund research to improve our understanding of the effects of offshore wind on the marine environment

• reduce the risk of not getting or delaying consent for offshore wind developments

• reduce the risk of getting consent with conditions that reduce viability of the project.

The programme pools resources from the private sector and public sector bodies to fund projects that provide empirical data to support consenting authorities in evaluating the environmental risk of offshore wind. Projects are prioritised and informed by the ORJIP Advisory Network that includes key stakeholders such as statutory nature conservation bodies, academics, non-governmental organisations and others.

The conference presentation will focus on sharing results from ORJIP Stage II. Projects for which we may share results include:

- Apportioning seabirds seen-at-sea – review current apportioning approaches and deliver of an improved apportioning tool for future offshore wind projects;
- Reducing conservatism in underwater noise assessments – results to inform future acoustic modelling for offshore wind projects;
- Quantification of mortality rates associated with displacement in the assessment process – provide more ecologically and geographically informed estimates of displacement-related mortality rates by species;
- Bird sensitivity mapping tool phase II – further develop the Seabird Sensitivity Mapping Tool;
- Range-dependent nature of impulsive noise (focusing on impacts on marine mammals);
- Integration of tracking and at-sea survey data (to further develop apportioning techniques for seabirds); and
- Prevalence of seabird species and collision events in offshore wind farms.

In addition to sharing these project results, we may share updates on upcoming projects under the ORJIP OSW programme.

Key words: Ornithology, Mammals, Collaboration,

PREDATOR AND PREY RESPONSES TO OFFSHORE WIND FARM CONSTRUCTION AND OPERATION

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The pace of offshore marine renewable energy development is increasing dramatically, to help meet national and international decarbonisation targets and increase energy security. The potential for marine renewables to negatively impact the marine environment is widely acknowledged and impact assessments routinely attempt to quantify these effects. However, considerable knowledge gaps exist around how offshore wind farms effect key ecological receptors such as seabirds and marine mammals. There is an urgent need to better understand how these receptors respond to offshore wind developments and the mechanisms that drive these changes, particularly changes to prey distribution. The five-year, multi-partner Predators and Prey Around Renewable Energy Developments (PrePARED) Project is utilising fish, seabird, and marine mammal data from two regions of east Scotland using telemetry studied (seabirds and fish), digital aerial surveys (seabirds), passive acoustic monitoring (cetaceans), acoustic surveys (fish), and trawls (fish). These data are being used to characterise broad and fine scale fish distribution, biomass, abundance, and behaviour, and to characterise predator distribution and behaviour in relation to prey, offshore wind farm construction and operation, vessel noise and environmental covariates. Outputs from the PrePARED project will be integrated into existing impact assessment tools such as interim Population Consequences of Disturbance (iPCoD), DEPONS, Seabirds and Offshore Renewable Developments (SeabORD), and the Cumulative Effects Framework (CEF) that has recently been developed for seabirds and marine mammals. The outcomes of the project will be increased confidence in the magnitude of cumulative effects, evaluation of positive and negative effects of offshore wind farm developments on key receptors, de-risking of consenting, improved post consent monitoring, better informed marine spatial planning, and understanding of fish distribution for fisheries co-existence. The PrePARED project also provides an example how collaboration with offshore wind developers to enable access to both the development sites and the data that they are collecting can significantly increase our collective ability to address critical knowledge gaps that may be barriers to the sustainable development of offshore wind farms. This oral presentation will provide an overview of the PrePARED project, work to date and some of the preliminary results.

Key words: bird, marine mammal, fish, cumulative, ecosystem

CONFLICTS OF AN OFFSHORE WIND FARM IN MARINE PROTECTED AREAS USING AN ECOSYSTEM APPROACH

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Canary Islands have the necessary elements to be a benchmark in the marine renewable energy sector, which would generate numerous jobs and significant growth in this region. In this study, we develop a spatial model to investigate positive and negative impacts during the exploitation of offshore wind farms (OWF) in marine protected areas, considering changes in marine biodiversity as well as potential use conflicts related fishing activities using an ecosystem-based approach. The hypothetical OWFs are in zones included in the Natura 2000 Network of the island of Fuerteventura. Suitability areas were selected based on Decision Support System INDIMAR, a tool to analyse offshore wind energy facilities into sea space in the Macaronesian region. The model evaluated different scenarios combining changes in species abundance due to attraction or repulsion, alternative fishing strategies and climate change. Our results suggested that the Ecospace model could potentially predict the effects of OWF on marine ecosystems and fishing, and the capabilities and limitations of ecosystem models for use as complementary tools for marine spatial planning were evaluated.
Key words: Ecopath, Ecospace, model, fisheries, offshore

ECOSYSTEM EFFECTS OF LARGE-SCALE IMPLEMENTATION OF OFFSHORE WIND IN THE NORTH SEA

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Development of offshore wind on the North Sea is progressing at a very fast pace, and it is expected that within a few decades a substantial part of the North Sea will be designated to offshore wind. Any kind of infra structure will have local effects on the ecosystem, but the potential scale of implementation of offshore wind may well produce effects on nearly every aspect of ecosystem functioning. In the Dutch offshore wind ecological programme (Wozep), we have carried out numerical model explorations to assess which areas of the North Sea may be susceptible to fundamental changes in ecosystem functioning. With a suite of coupled state-of-the-art models, we have run scenarios without any wind farms and with different upscaling scenarios. Earlier studies (using a hypothetical upscaling scenario indicated that there were likely very significant effects on processes such as stratification and fine sediment dynamics. Different parts of the North Sea respond differently to the placement of offshore wind farms. Recent follow-up work has focussed on improving the model, validating the effects in and around wind farms. Field observations in a Belgian wind farm confirmed the presence of wakes behind turbines where near-bed water was mixed with surface water. The second new development is the implementation of filter feeders such as mussels on the turbine supports that grow in direct competition with zooplankton. The combination of large amounts of benthic grazers in the upper water levels and more exchange between different water layers and hence more transport of food towards the bed could in theory affect the ratio of carbon fluxes between benthic and pelagic components in the marine food web. Within this project we are trying to understand the bottom-up effects of offshore wind on the North Sea food web and the potential knock-on effects on higher trophic levels. With the current developments in this ecosystem model, we are setting a further step in this direction.

Key words: Ecosystem impact, offshore wind, stratification, primary production, food web

EXPLORING THE NEED FOR ECOLOGICAL RESTORATION IN ONSHORE WIND ENERGY PROJECTS

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Introduction: Onshore wind energy is expanding rapidly, increasing the pressure on biodiversity and habitats by causing ecosystem degradation. Due to the prominent role of wind energy in the transition to renewable energy, there is an urgent need to understand how the restoration of vegetation, soils, and hydrology in onshore wind power plants (WPPs) can counteract habitat loss and safeguard biodiversity. Methods: This literature review collected information from scientific studies, environmental impact assessments, and construction manuals and guidelines for WPPs, to: 1. Summarize short- and long-term effects of WPPs on vegetation, soils, and hydrology, 2. Analyze the implementation of ecological restoration in each stage of onshore wind energy projects (planning, design, construction, operation, and decommissioning), and 3. Discuss the need for ecological restoration in onshore wind energy projects based on findings from the literature review and lessons learned from other examples of infrastructure and energy development. Results: WPPs can have a larger ecological footprint than previously acknowledged. Their construction and operation can significantly alter plant species composition and vegetation structure, challenging their ability to recover naturally. Soils are heavily disturbed during construction and decommissioning, which can have a subsequent effect on nutrient cycling, hydrology, and plant species composition. Changes to local hydrology can affect large areas and threaten sensitive peatland systems by altering plant species composition and soil microbiology. In general, WPPs induce complex changes to vegetation, soils, and hydrology, and have the potential to severely degrade natural ecosystems. Despite this risk, it was found that the need for ecological restoration is not properly realized and only considered towards decommissioning in most onshore wind energy projects. Conclusion: Onshore wind energy is a promising renewable energy source but WPPs have the potential to severely degrade natural ecosystems. More research is needed to understand their effects on vegetation, soils, and hydrology, to mitigate ecosystem degradation. Despite the efforts on early mitigation, the extent and complexity of ecosystem degradation caused by WPPs showcases that ecological restoration is urgently needed in onshore wind energy projects. However, the potential to restore degraded ecosystems is limited, and extreme changes to soil properties and hydrology are hardly reversible. As a result, WPP operators need to consider compensation for areas that cannot be restored, by preserving or restoring ecosystems elsewhere, in addition to on-site restoration.

Key words: onshore wind energy, ecological restoration, habitat loss, soil disturbance, biodiversity conservation

PORPOISE NETWORK BORSSELE: LONG-TERM STUDY ON THE HABITAT SUITABILITY OF OFFSHORE WINDFARMS FOR HARBOUR PORPOISES IN THE NORTH SEA.

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The Dutch government has set ambitious goals for the development of offshore wind in the North Sea. This development potentially has a large impact on the marine environment, and is therefore closely monitored by the government by means of the integral research program WOZEP (Offshore Wind Ecological Programme). The overall objective of WOZEP is to address knowledge gaps on the cumulative impact on protected species of the North Sea ecosystem. As part of WOZEP, the Porpoise Network Borssele project was initiated to study the habitat suitability of offshore wind farms for harbour porpoise (Phocoena phocoena). Since an increasing area of the North Sea is being reserved for future OWF development, the suitability of these areas for harbour porpoises is essential to ensure that the population is not negatively impacted. In this five-year project that started in 2021, harbour porpoises are studied by means of a Passive Acoustic Monitoring network consisting of 14 measuring stations inside and outside the Borssele OWF. At these stations, both presence of porpoises and underwater noise as (anthropogenic) pressure are monitored. Research focusses at gaining insight in the use of the OWF by porpoises in comparison to areas outside the OWF. The maintenance of this extensive PAM-network requires extensive cooperation between parties involved, such as the OWF operators, government, research institutes and the (governmental) vessels from which offshore work is being executed. Collected data is integrated in the WOZEP data management portal, from which data can be shared with other research projects. The PAM network specifically aims to facilitate other research initiatives in OWFs and provides a platform for offshore cooperation. Researchers of other projects regularly join on board of the vessels, e.g. to study the impact of electromagnetic fields of subsea power cables or to conduct visual observations of porpoises and seabirds in- and outside the OWF. The PAM network forms a central project in a variety of WOZEP research projects, such as the study that analyses visual data of porpoise behaviour and presence in OFW. Data and knowledge gained in these projects are integrated in WOZEP with the aim to address knowledge gaps and assess the impact of large-scale future wind development on the Dutch North Sea ecosystem.

Key words: harbour porpoise, PAM, underwater noise, habitat suitability, OWF.

BENTHIC ENVIRONMENTAL FOOTPRINT OF AN OFFSHORE WINDFARM: A NOVEL STUDY

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Goal: Apply the latest technologies to investigate how offshore wind farms affect benthic biodiversity and function – focusing on biodiversity (eDNA, macrofauna) and blue carbon. Material and methods: Seabed sampling from a research vessel in July, 2023 at increasing distances along a gradient around an offshore wind farm (OWF) to identify any impacts, including a reference site for each gradient. Sediment will be collected using a corer, and a Sediment Profile Imaging (SPI) camera to take images of the seabed at the sediment-water interface. At each sampling station, replicate samples will be collected for: • Biodiversity analyses – macrofauna (traditional taxonomy); eDNA (qPCR and next generation sequencing) in surface (0cm) and sub-surface (5cm depth) samples – this eDNA targets the microbial communities in the oxic surface sediments and the hypoxic / anoxic sub-surface. The eDNA work will also link to a PhD which aims to develop an eDNA toolkit for macrofauna (e.g. primer development). • Chemistry – sediment samples will be collected at 0cm and 5cm and analysed for metals (chromium, copper, nickel, lead, zinc, strontium, barium), nutrients (ammonium, nitrate, phosphate, silicate, nitrite), and hydrocarbons (total PAH's and n-alkanes) as well as oxygen profiles and inorganic as well as organic (blue) carbon • Radiochemistry analyses – this links to the carbon work, and Radium 226, Lead 210 and Caesium 137 will be measured to allow aging of sediment layers (and estimation of sediment accumulation rate, linked to carbon stocks) • Particle size analyses – for each of the carbon 'slices' of sediments – will inform on sediment type and link to the chemistry and carbon Each station will also have sediment profile images, so a crosscut section of the sediment and overlying water – easy identification of burrows and oxic layers in the sediment.

Key words: benthic biodiversity, eDNA, carbon

SCIENTIFIC VALIDATION OF AI BIRD-MONITORING SOFTWARE - BEST PRACTICE AND EXPERIENCES FROM ABERDEEN BAY – A COLLABORATIVE PROJECT BETWEEN VATTENFALL, THE BRITISH TRUST FOR ORNITHOLOGY AND SPOOR.

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Monitoring collisions offshore is a key part of strategies to overcome challenges to the consenting process, driven by estimated collision rates. We aim to address this by combining high-resolution video cameras and AI software to track and identify seabirds at the European Offshore Wind Deployment Center (EOWDC), off the coast of Scotland. Following a pilot on the same site in 2022, an extended deployment and trialing of the technology will take place during 2023, filming and analysing bird activity around two wind turbines at the site. Validation of the resulting data is critical to ensuring that bird-monitoring systems deliver valuable and reliable data. Furthermore, novel analytical approaches will be required in order to get the most out of these data. Recognising this, we aim to: 1) Carry out independent validation of the AI System Data by BTO 2) Develop methodologies to analyse data collected in order to quantify avoidance behaviour and account for any uncertainties in the data. 3) Capture a larger dataset on bird activity in the EOWDC windfarm, providing insights into patterns of bird-behaviour over a larger area and a longer period of time. 4) Trial a stereo-vision camera configuration and compare the precision of this system (particularly bird distance and flight height measurements) with mono-camera estimations. We present the initial results from our study covering data collection in spring-summer 2023. Based on our experiences, we highlight how studies such as this can be used to evaluate and refine data-acquisition of bird activity offshore, and how this can support scientists and regulators by significantly improving the modeling of the scale of collision impacts.

Key words: AI, bird-monitoring, offshore, cameras

CHALLENGES OF CURTAILMENT ALGORITHMS FOR BATS IN FARMLAND AND INDUSTRIAL AREAS

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Stopping blade rotation when the bat activity is high is an efficient mitigation measure to reduce the impact of wind energy on bats. These curtailments are widely implemented in Europe, with various levels of bat protection and various amounts of energy production losses. Wallonia (south Belgium) has recently fixed probably the highest standard of bat protection in the world. It is now required for each turbine to be stopped during 90 % of bat activity at hub height, measured as the number bat passes recorded between April and October, for each species. This new rule is progressively implemented in each wind farm, most of the time by assessing a combination of 4 thresholds: wind speed, temperature, rain and time after sunset, so called “abiotic parameters”, deduced from one year of bat recording at hub height. We did this assessment for 17 turbines between 2018 and 2022 (1,652 bat passes/turbine/year on average). We have highlighted three weaknesses of this approach in the case of wind farms where bat activity is low. First, the relation between bat activity and the abiotic parameters is not constant but vary from year to year. In one site, the wind speed threshold calculated based on 2020 recordings is 5,3 m/s while it reaches 8,5 m/s in 2022. Second, statistical analysis that are required to calculate thresholds are not robust when the total activity is low. For example, in one site, 42 % of the bat activity during the year has been recorded in only two nights. This helps to understand why the results of the parameterization sometimes strongly vary from year to year. Third, the wind speed threshold calculated to fit the legal requirements often reaches ~6,5 m/s (average : 5,9 m/s, min. : 4,2 m/s; max. : 8.5 m/s). Such high thresholds induce 3 to 4 % of power losses, a significant loss in the business plan of some wind farms according to the wind operator. This study highlights that the present-day usual strategy for protecting bats at wind farms in Wallonia is often very reliable but has some weaknesses and sometimes fails in reaching every year the expected protection levels. In parallel, relative production losses are significant according to companies that are operating wind farms. This highlights the need for more efficient tools or methods to trigger turbine stops to avoid collisions as much as possible while limiting production losses.

Key words: bat, mitigation, mortality, Belgium, Wallonia

TESTING OF A BAT ACTIVITY AND MORTALITY DETECTION SYTEM FOR UTILITY SCALE WIND TURBINES

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Blanket curtailment of wind turbines is the primary bat mortality reduction strategy in practice today. While curtailment can significantly reduce bat mortalities, on average by 50%, this method results in power production losses. Research indicates bats are only active around a turbine for a fraction of the total curtailment time meaning that energy loss occurs when bats aren't present. Thus, there is interest in finding ways to reduce bat mortality that lessen these power losses by identifying other conditions influencing mortality rates to inform when turbines should be curtailed, a strategy often termed smart curtailment. Our objective is to test if a newly developed ground-level thermal camera system is capable of detecting when bat mortality occurs and thus conditions associated for informing smart curtailment algorithms. Our hypotheses are that the camera system will: 1) accurately detect when bat mortalities occur by documenting when bat carcasses land at ground-level, and 2) provide an estimate of bat activity measured below the rotor swept area. We predict these metrics will allow for improved site-level risk reduction strategies for bats. From July through October 2022, we deployed a thermal camera-based system around two operational wind turbines in southern Texas, USA. Daily carcass searches were conducted four days a week (Tuesday - Friday) at the 2 turbines and the searches covered 150 m by 100 m rectangular plots around the wind turbine to match the area covered by the camera system. Each found mortality had its physical location and time recorded by technicians in ArcGIS Field Maps. We matched bat carcasses discovered during searches with camera-based mortality detections to not only validate the system's ability to detect when a carcass lands on the ground, but also determine exact timing of mortality and conditions present. We calculated a detection rate for the system by comparing the number of carcasses found in manual searches to those found by the automated systems. In addition to the mortality data, we will share very unique data that compares the bat activity in the turbine rotor sweep to that which occurred below the rotor sweep. These data could have profound implications on how we understand bat mortality risk and the means for reducing it.

Key words: bats, thermal camera, curtailment, mortality monitoring, activity monitoring

AVES - AUTOMATIC VERIFICATION SYSTEM - AN AUTOMATIC IDENTIFICATION SYSTEM TO REDUCE MORTALITY RISK BY COLLISION AND DOWN TIME OF WIND TURBINES

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The growing number of wind turbines with increasingly larger rotors and total heights leads to conflicts with legal provisions for protected bird species, which are exposed to a higher individual risk of collision mortality. Thus, areas with a potential for energy production may not become available for regenerative energies or seasonal (and costly) shutdowns may be required. To solve this problem, BioConsult SH is developing AVES, a system aiming to avoid bird collisions. AVES is a camera-based bird detection system installed directly on the tower of the wind turbine. The performance of the system is evaluated and monitored in a research project conducted between 2021 and 2023. Evidence of effectiveness is currently being provided in a wind farm in Schleswig-Holstein in Germany. Robust, weatherproof, high-resolution network cameras with pan, tilt and zoom options as well as an infrared light source supporting night vision are used. AVES detects moving objects in a range of approx. 1,000 m (depending on the object size). If a large bird is identified and classified as target species and is further approaching up to a specified distance from the turbine (reaction range), a signal transmitted to the wind turbine will reduce the rotational speed (idling) until the bird leaves the area. To achieve reliable identifications as well as high spatial and temporal coverage, the system applies different parameters to detect and automatically recognize the species: A tracking system uses camera images to detect and track birds. A neural network processes the incoming video stream and detects birds, and after zooming in also if the bird belongs to the target species as soon as enough pixel information is present. For distance measurement of the species from the wind turbine we use two different approaches, one is computed based on the camera zoom level and the typical real size of the identified species as compared to their pixel size in the video stream and the other approach is a distance measurement using triangulation with two cameras on two different wind turbines. If the flight direction leads into the reaction zone and the bird is classified as target-species, the system will send a command to the wind turbine to either shut down or lower the rotational speed of the rotor. This camera-based system will reduce the mandatory shutdown times from a general shutdown to an on-demand short-term shutdown lasting only a few minutes during risk scenarios.

Key words: bird, collision, wind turbine, detection, shut down

THE USE OF PASSIVE ACOUSTIC SURVEYS TO MONITORING AVIAN COMMUNITY AT WINDFARMS IN PORTUGAL: A COMPARISON WITH A PROXY OF A STANDARD HUMAN SURVEY

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Passive acoustic surveys have been successfully used to monitoring bats at wind energy facilities and is making is way in avian monitoring. The main challenge inherent to this method is processing the great volume of data recorded and to correctly identify the species that are vocalizing, to derive the subsequent parameters. In Portugal, standard avian monitoring protocols in windfarm facilities include a human observer (listener) that surveys 5 to 10 minutes in a fixed point and then travels subsequently to the next ones in the first hours of the day. We wanted to test the use passive acoustic surveys to monitor the avian community in a windfarm area and here we present the first results and a comparison with a proxy of a standard human survey. Field protocol involved 8 AudioMoth recorders distributed across study area. Each device registered 10 minutes of acoustic data followed by 10 minutes of recess, during a time span of 4h, starting 30 minutes after sunrise. Obtained data was partitioned in two sets: one was used to simulate standard human survey (Acoustic Proxy of Human Survey Data- APHSD), included only 10 minutes of records at each sampling point; the other encompassed all records obtained simultaneously by all equipment (Simultaneous Acoustic Data – SAD). A workflow was developed using Python and R programming to process recordings and bioacoustics results, and data was analysed using BirdNet. Data validation was made on 5% of outcomes by experienced ornithologists. Paired Samples t-test was used to compare acoustic datasets. T-tests showed that SAD yield a statistically significant high volume of data. In relation to sound events, APHSD represented only about 16% of the total volume of data obtained with SAD. Monthly, about 50% of species can be unregistered with APHSD, and after all period analysed, 27.9% of species were unregistered with APHSD. Despite the significant differences between volume and species assemblages recovered with each dataset, temporal patterns of avian activity as well as spatial patterns at control and impacted areas were similar. At this point, it is possible to confirm the potential of passive acoustic bird recording to monitor avian communities at wind energy facilities. Besides the evident higher volume of data, this method has other advantages, including the opportunity to access the presence and behaviour of bird fauna at night, to obtain data from different places simultaneously, and to gather data at large spatial scale with less costs associated.

Key words: Avian monitoring, autonomous records, auto-identification, BirdNet, bird assemblages

THE SCOTTISH PASSIVE ACOUSTIC NETWORK (SPAN): A NATIONWIDE BASELINE UNDERWATER SOUND AND MARINE MAMMAL MONITORING APPROACH

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The potential for offshore wind energy development in the seas around Scotland is considerable, with over 4.5GW of capacity currently constructed or under construction. To help achieve the target of net zero by 2045, The Crown Estate has recently leased several option areas around the coast through the ScotWind leasing round, with the potential to generate 27.6GW of energy for Scotland. These include locations on the west and the north coasts of Scotland, which to date have no offshore wind farms. With the development of new technologies such as floating platforms, windfarms have the potential to be constructed in deeper areas, further offshore than previously possible. The construction and operation of offshore wind farms poses potential threats to marine wildlife. Marine mammals are of particular concern when planning for the build-out of marine renewable projects at scale. Impacts may occur at all stages of development but underwater noise, particularly during the construction stage, has the potential to injure and/or disturb numerous species of marine mammals, in addition to other taxa such as invertebrates and fishes. The planned expansion of offshore wind into more remote waters requires us to address the knowledge gap of what species occur in these areas and when. Some of these regions are known to host poorly studied or data-deficient marine mammal species, for which we hold little to no baseline distribution or relative abundance data. Additionally, baseline ambient underwater sound levels in these regions are not empirically known. Passive acoustic monitoring can provide both detections of vocalising and echolocating marine mammals as well as recording natural and anthropogenic underwater sound. The Scottish Government are expanding the decade-long East Coast Marine Mammal Acoustic Study (ECOMMAS), comprised of 30 coastal moorings, to cover the full extent of Scottish waters. An additional 23 sites across the east, west and north coasts, as well as 2 sites proximal to Shetland, will now be monitored year-round. Each mooring holds a cetacean click detector and a broadband sound recorder. This nationwide network will provide strategically valuable outputs relevant to the planning and delivery of offshore wind farms including baseline species occurrence and relative abundance, seasonal variations, changes in relative abundance over the duration of the ScotWind build-out phase and comparisons of regional underwater sound levels before, during and after construction. The broadscale data collected from this strategic project is publicly available and will inform scoping reports and environment impact assessments going forward.

Key words: acoustic, monitoring, marine mammals, noise

MAVEO PROJECT (MARINE VERTEBRATES & OFFSHORE WIND FARMS): A TOOL FOR ECOLOGICAL MONITORING AND ASSESSMENT IN THE OCEANS

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To increase the knowledge on the marine environment around the future Dieppe, le Tréport offshore windfarm, EMDT developer, BIOTOPE ecologist expert, and AKROCEAN, a buoys' supplier to collect meta-ocean and biological data have joined forces to provide a self-powered multi-instrumental tool to monitor and assess marine biodiversity. The floating marine observatory, based on AKROCEAN's FLYR'SEA technology, is a station at sea embedded with state-of-the-art measuring instrumention, such as Aerial and underwater acoustics, video and radar system, multi-parameters probe. Those instruments collect simultaneously, data on each of the marine vertebrate groups (avifauna, bats, marine mammals and ichthyofauna), as well as physical, meteorological, and hydrological data to characterize the habitat of vertebrates. The buoy enables to collect 365 days a year of reliable and accurate data with notably hosting a bird radar usually installed on fixed asset or coastal area. Those non biological data as well as information about the working status of the station could be transmitted in real time (GSM network) to the operator. A data analyses service is provided with the station to extract bioindicators for each marine aquatic and aerial compartments and at their connection point. The station is self-sufficient in energy to ensure the acquisition of temporal data representative of the study area. Our objective is to acquire knowledge of the marine environment using an ecosystemic approach. The observatory can simultaneously follow the migratory flow of birds, assess the variation of fish biomass over time, detect the presence of bats and evaluate the frequentation of marine mammals around the buoy. The correlated analysis of these biological compartments associated with meta-oceanic data provide rich and unique datasets. Those datasets will contain valuable information on the medium and long-term effects of the construction and operation of wind farms but will also help to improve our scientific knowledge of marine ecosystems, and answers to the environmental questions of today and tomorrow. This world premiere tool at pre-commercial scale level is fully in line with the current deployment of offshore windfarms which creates a very strong demand to produce robust and reliable ecological data in order to obtain relevant data directly useful as decision-making tools for studies impact, surveillance and assistance in the administration of Marine Protected Areas. With offshore wind farms increasingly distant from coast, needs for such solution might be vital to gather key information especially for environmental impact assessment and impact monitoring.

Key words: Buoy, ecological monitoring, bird radar, offshore, multi-instrumental

EXPLORING THE POTENTIAL OF NAVIGATIONAL RADARS AND SURVEILLANCE CAMERAS TO MONITOR BIRDS IN A FLOATING OFFSHORE WIND FARM AREA

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Globally, many bird populations are in decline, and offshore wind farms (OWFs) might further increase the stress on these populations. There is a need for further knowledge to improve estimates of OWF and bird collision risk and to understand the potential displacement and subsequent effect for the relevant bird populations. Using the world's largest floating OWF, Hywind Tampen, as the area for monitoring of bird activity, the wind farm operator Equinor and research collaborators have tested the potential of navigational radars to monitor birds. The upside of use of navigational radar for monitoring is the increase in knowledge of bird activity data from remote offshore areas where O&G installations with radars are located. During spring 2023, standard surveillance cameras will also be used for monitoring of bird activities. The technologies are normally used for controlling ship activity in close vicinity of offshore facilities (radar) and safety for workers (cameras). Hence, these studies explore the potential use of existing infrastructure in the area around a FOWF, and equipment mounted on the turbines, to gather data on bird activity and attendance. In a pre-study, the navigational radar system at the O&G platform Gullfaks C was used to detect bird data in the north-east direction, towards Hywind Tampen, during 2022. In the autumn 2022, an identical radar was also placed on the island Fedje, on the coast of Norway, in the area where birds gather prior to autumn migration towards the British Islands. An advanced Robin MAX avian radar, placed on Fedje, as part of another research project, has been used for validation of the navigational radar systems. The results from the radar studies show that the navigational radar is well capable of detecting bird tracks. However, in comparison to the advanced avian radar, the detection range is limited both regarding distance and altitude (max 3 km/350 m height). Sea clutter and rain are also challenging, especially for offshore environments. From April 2023 the standard surveillance cameras at Hywind Tampen were taken in use for monitoring of birds in the vicinity of the OWF. The data will add knowledge on bird presence and behavior in the area as well as giving an opportunity for assessing use of existing infrastructure in wind farms for bird monitoring.

Key words: wind farm, bird monitoring, radar, camera

RESTORATION OF SEAGRASS MEADOWS AFTER MECHANICAL DAMAGE: INCORPORATING BIOMIMICRY AND RECOVERY OF FEEDBACKS IN RESTORATION TECHNIQUES

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The impact of offshore wind in de the Mediterranean Sea will likely include impacts on seagrass meadows[1], for example within cable routes where seagrass will be destroyed or fragmented due to mechanical damage and changes in water quality and turbidity. Meadows of the seagrass Posidonia oceanica are the most important vegetated marine ecosystem in the Mediterranean Sea and renowned for their complexity, persistence, and extension as well as fragility. These seagrass meadows provide valuable ecosystem services e.g. carbon storage, water quality improvement, fish nursery and biodiversity. Despite their central role in the coastal ecosystem, as well as climate change mitigation, Posidonia meadows are undergoing overall deterioration due to anthropogenic impacts like coastal modification, water quality deterioration and mechanical damage[2]. Assessing the success of ecological restoration techniques aiming at repairing mechanical damage caused by human activities is thus critical to justify mitigation and use restoration measures to counteract negative impacts of current and planned practices in offshore wind. A seagrass vegetation transplant experiment in Posidonia meadows (Corsica, France) has been initiated to restore areas degraded by mechanical damage. Posidonia fragments were transplanted from storm-generated fragments into a 'scarred' meadow[3]. Biodegradable matrix structures were implemented to facilitate the seagrass plant survival, establishment and natural recovery process. These structures are designed to temporary mimic natural seagrass meadows – the complexity of dense root mats – and aid the recovery of natural feedbacks[4]. The biodegradable matrices have been tested on a global scale with restoration designs of different seagrass species[4,5]. Results of this global experiment demonstrate the structure greatly enhanced yields when seagrass is transplanted within structures mimicking emergent traits that suppress waves or sediment mobility[4]. The new study aims to advance knowledge on the facilitation of Posidonia development in meadows that are mechanically damaged. Preliminary results from the transplant experiment, that is followed over time, will be discussed in the context of 1) repairing mechanical damage in seagrass meadows and 2) similar transplantations in seagrass meadows throughout the globe 3) future options for

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Key words: seagrass, impact, mitigation, restoration, biodegradable

MONITORING HYDROLOGICAL CHANGE DURING AFFORESTED PEATLAND RESTORATION: A CASE STUDY AT AN UPLAND WINDFARM IN SOUTH WALES, UK

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Widespread across the European continent, peatlands are environmentally important landforms that store more carbon than any other type of terrestrial ecosystem. Often, they form in upland environments featuring high precipitation and cool temperatures, where, prior to the widespread afforestation of upland peatlands during the second half of the last century, agricultural improvement was limited. However, the conditions of these upland environments are suitable for wind energy production. Today many windfarm developments are co-located with existing conifer plantations on peatlands, as exemplified in Pen y Cymoedd, South Wales. As the UK's highest altitude windfarm, Vattenfall's 76 turbines are situated on the afforested upland peatlands that are part of the Welsh Government (national) woodland Estate. Here, as part of the planning permission for the wind farm, Vattenfall is working in partnership with Natural Resources Wales on a £3 million, 25-year project to restore 1,500 ha of afforested peatlands post tree-felling through a process known as 'forest-to-bog' restoration. Whilst existing literature emphasises the importance of hydrology in maintaining peatland condition and functionality, few studies have evaluated the outcome of forest-to-bog restoration or assessed the extent to which favourable ecohydrological conditions can be re-established. Furthermore, the behaviour of subsurface hydrological processes remains poorly understood and is often oversimplified in existing literature. Our research will employ geophysical techniques including ground-penetrating radar and self-potential surveys, which, paired with geomapping, modelling, and field-based data calibration, may demonstrate an innovative method of surveying the subsurface physical and hydrological properties of peatlands without the barriers associated with conventional methods (time and labour demanding, environmentally invasive). In addition, with reference to variables defining intact peatlands, this study will quantify ecohydrological changes at various phases throughout forest-to-bog restoration, helping to update current understanding and inform operational best-practice and policy, both within and beyond Wales.

Key words: Peatlands, Hydrology, Windfarm, Geophysics

MULTICOPTER BAT SURVEILLANCE: NOISE EMISSION VERSUS THE HEARING ABILITIES OF BATS

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Covertly monitoring bats to obtain information on their population size and species in hard-to-reach areas is challenging. By attaching an acoustic sensor to a multicopter (MC), a large area can be covered without the limitations experienced by sensors mounted at fixed locations. It has previously been shown that the emitted MC noise may either attract or deter the bats. Although the cause of this effect is still unclear, we reveal that some bat species can perceive the emitted noises even far away from the MC, whilst other bat species do not hear the MC. We measured the sound pressure level of multiple drone drivetrains up to a frequency of 100 kHz in the laboratory and applied a two-stage environmental damping model of sound. A cylindrical model for free field sound propagation was used to simulate the worst-case geometrical attenuation of sound propagation in air. This model depends on the radiation characteristic and the distance from the point source. In addition, the atmospheric model simulates the effect of molecular absorption in the air and is dependent on the distance from the object, relative humidity, atmospheric pressure, and temperature. We further investigated the effect of temperature and humidity on noise attenuation for the atmospheric model and the best possible scenario is recommended. The auditory brainstem response (ABR) data of 38 bat species were overlaid with our simulated attenuation results to draw conclusions in which frequency ranges and to what extent the emitted sound pressure level could possibly be heard by the bats. We can conclude that there are many bat species that will not hear the MC, but there are also some bat species that will hear the MC. The analysis of several drivetrain combinations indicates that the propeller is the most noise-emitting part of MCs. The noise emission of MCs is clearly dependent on the thrust level, size, and shape of the propeller.

Key words: Bats, noise attenuation models, noise emission, multicopter, auditory brainstem response

OPTIMIZING UAS FOR BAT ACTIVITY MONITORING NEAR WIND TURBINES: INVESTIGATING DETERRENT AND HABITUATION EFFECTS

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The protection of bats (Chiroptera) around wind turbines requires a better understanding of bat activity in the vicinity of these structures. Currently, stationary nacelle monitoring is used to determine bat activity levels at greater height. However, this method has limitations as it covers only 4% of the risk area for bats with echolocation calls of 40 kHz (assuming a 60 m blade length). Additional data could be collected by Unmanned Arial System (UAS), to reduce bat fatalities while optimizing shutdown times for individual wind turbines and improve the planning of new wind turbine installations. The goal of this study is to investigate whether optimized UAS have a deterrent or attraction effect on bats and whether bats become accustomed to the presence of UAS over time. In a previous study in 2022, we recorded the bat activity levels starting 30 minutes after sunset until 4 hours later in altogether 24 nights. An acoustical bat detector was installed at two meters height facing vertically upwards. Subsequently, we recorded bat activity while a large multicopter UAS was hovering in 20 meters height above the bat detector and without the UAS (control). Bat activity was significantly lower in presence of the UAS, however this deterrent effect was small. We assume that this small effect could be explained by the experimental set-up, since bats cannot fly near the multicopter due to strong air turbulence and thus avoid UAS. In the present study we collected data using an optimized multicopter, with reduced acoustic and light emissions. While keeping the original bat detector facing upwards for the comparability of the results, we installed a second bat detector directed towards the ground 10 meters below the UAS, hovering at 22 meters height. This setup represents real-life conditions, as it will be suspended 10 meters below the UAS in a downward-facing orientation. Further, we studied the habituation effect of bats towards the multicopter by analyzing the effect of time on bat activity. We expect no or a smaller deterrent due to the optimized set-up and technical changes made to the multicopter. We further expect no difference in bat activity between the recordings taken by the bat detector directed towards the ground and the control. If this method does not exhibit a deterrent effect, we will be able to collect data on bat activity at the upper end of the wind turbine for the first time.

Key words: Bats, UAS, Deterrent and Attraction Effect, Acoustical Monitoring

EVALUATION OF THE EFFECTIVENESS OF IDENTIFLIGHT & RESIDUAL IMPACTS ON THE RED KITE (CôTEAUX DU BLAISERON WIND FARM - GRAND EST - FRANCE

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In response to red kite collisions with wind turbines, Boralex, an international windfarm company, installed the IdentiFlight system on the Côteaux du Blaiseron wind farm (France). As required by practice and administrative demands, every technological tool must be effective. Since such a tool cannot achieve absolute perfection, it is thus also necessary to consider the residual impacts. Boralex entrusted these two tasks to Ecosphère during the year 2021. Several of the objectives have been validated (machine downtime, overall identification performance, etc.). However, IdentiFlight does not meet all the objectives expected in terms of detection, given the importance of the notion of groups for migration. Nevertheless, it is possible to provide a different objective based on protection by correct shutting down and not correct detection. The case of groups of birds is then better covered. IdentiFlight is probably one the most interesting technology currently available for reducing impacts on the red kite (large detection distance, specificity of the curtailment), but its investment cost is very high. However the estimated production loss represents only 2.5% of the total production in the studied site. In 2021, over the study period, more than 76% of the kites were covered by wind turbine curtailment, with only 19% of them flying within 100 m of the wind turbines (higher but not certain risk of collision). Since then, the software was improved in 2023 (classification speed has been deeply growned up to address the multi tracking topic). Finally, the wind farm continued to be the subject of enhanced mortality monitoring (2020 to 2022), and no bird of prey cadavers have been identified since March 2020 and an analysis of redidual impacts for the red kite was proposed.

Key words: IdentityFlight, Red kite, mitigation

ASSESSING THE COMPARABILITY OF DIFFERENT AERIAL MONITORING METHODS OF MARINE MEGAFAUNA

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The development of offshore wind farms (OWF) has raised concerns about its potential impacts on wildlife, particularly marine megafauna. To accurately assess changes in the distribution and abundance of seabirds and marine mammals, reliable impact studies are required. In the context of OWF development, initial assessments are typically conducted using visual aerial surveys (with onboard observer) prior to construction. However, subsequent monitoring over the life cycle of OWF will require to flight at higher altitudes than before construction for safety reasons. At such altitudes, digital aerial methods (with onboard cameras) are required. Such changes in monitoring methods can have huge consequences in the variables of interest and lead to bias in the impact assessment of windfarms. Procedures that ensure that abundance and distribution estimates are comparable over time are thus crucially needed. In this project, we compare the estimates of population abundances using different methods notably human observers at low altitude (~180m) and automated data acquisition systems at both low and high altitude (>300m). We performed that comparison on ten aerial monitoring surveys of marine megafauna. Preliminary results indicate that digital methods detected more animals on average than visual methods, resulting in higher estimates of abundance in the studied areas. Yet, the magnitude of the difference in estimates depends on the species studied. For example, discrete species such as alcids, which are relatively small and dark, were much more detected by digital monitoring than by visual monitoring. In contrast, species that are easier to detect visually, such as gannets, were about equally detected by all approaches. We also tested whether comparability of methods depended on other factors such as species abundance or weather conditions. Overall, these findings highlight that ensuring comparability of different monitoring methods is a complex task that depends on multiple criteria. Our work pleads for a detailed consideration of detection processes when estimating abundances of megafauna species both visually or though video or photographs to insure their comparability over time.

Key words: digital aerial monitoring, visual aerial monitoring, intercalibration, marine megafauna

IMPLEMENTING MOTUS TECHNOLOGY FOR OFFSHORE WIND MONITORING

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The Motus Wildlife Tracking System ('Motus'; https://www.motus.org) is an international collaborative research network that uses cooperative automated radio telemetry to track transmitters on coordinated frequencies. Over the past two years, we led an interdisciplinary effort to develop standardized protocols for using Motus to monitor birds and bats in offshore environments of the U.S. Atlantic (https://motus.org/groups/atlantic-offshore-wind/). Further, we developed tools to assist collaborators in implementing Motus studies offshore, including: 1) detailed guidance for deploying and operating Motus stations on offshore wind energy infrastructure; 2) study design tool (IDIOMS) to inform the placement of Motus stations at offshore wind sites; 3) data framework to coordinate and disseminate Motus data for the U.S. Atlantic via the Motus Wildlife Tracking System; 4) monitoring recommendations for using Motus in relation to offshore wind energy development, including guidance for coordinated tag deployment; and 5) modelling of offshore animal movements relative to Motus receiver detection ranges to understand the probability of transmitters being detected by networks of offshore receivers. Ongoing work through Project WOW (Wildlife and Offshore Wind; https://offshorewind.env.duke.edu/) is focused on the development of models to estimate the three-dimensional locations of tagged animals from Motus detections. Motus data for seabird and shorebird species of regulatory interest are also being used to parameterize new collision risk models for these taxa in relation to U.S. Atlantic offshore wind energy development. Offshore Motus stations are now deployed on several monitoring buoys and three wind turbines in the U.S. Atlantic, with plans to install additional stations as new offshore wind projects are developed. This presentation will address current efforts for integration of Motus with offshore wind monitoring plans, including study design considerations, station calibration, automated reporting, and use of data in risk assessments. We will also explore how these methods are being used in the U.S. Atlantic to improve our understanding of the offshore movements and habitat use of key bird species.

Key words: automated radio telemetry, bats, birds, Motus Wildlife Tracking System

FIRST RESULTS OF THE LIFE EUROKITE PROJECT: HUMAN-CAUSED MORTALITY OF THE RED KITE IN EUROPE ASSISTED BY HIGH-RESOLUTION GPS TELEMETRY TRACKING.

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The main goal of the LIFE EUROKITE project is to reduce anthropogenic causes of mortality of the red kite in Europe. The efficient protection of the red kite requires the detailed understanding of overall mortality reasons, especially focusing on those caused by legal and illegal human activities. The LIFE EUROKITE project focuses on a Europe-wide representative sample which is achieved by using high-resolution GPS telemetry tracking of 2,321 tagged red kites from 14 European countries, allowing fast and exact locating of dead birds. This considerable database is only possible through cooperation and data exchange with multiple international partners. By 25/04/2023 more than 975 red kites have already died (not including transmitter failures). Using a standardized protocol for the European-wide assessment of morbidity and mortality of raptors by performing necropsy procedures, it has been proven that 138 of 751 completely analysed tagged red kites have died from poisoning. In total, 355 tagged red kites have died from anthropogenic causes such as poisoning, collision, electrocution and shooting. We used the "integrated Step-Selection Function (iSSF)" to learn the behaviour of tagged red kites and predict the species-specific probability of anthropogenic mortality factors of red kites across countries and regions in Europe. Only by using such large and European-wide telemetry-assisted datasets unbiased results of human-caused mortality of red kites can be obtained. This is essential to take appropriate measures for the protection of the red kite.

Key words: Red Kite, Mortality, Europe

SEMMACAPE: AERIAL SURVEY OF THE MARINE MEGAFAUNA IN OFFSHORE WINDFARMS BY AUTOMATIC CHARACTERISATION

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Project developers must produce environmental impact studies, particularly on marine megafauna (birds, mammals, turtles, big fish…). The analysis of the impacts of an offshore floating windfarm project requires aerial observations of marine megafauna in order to better characterize the frequentation of species in the proposed areas. This includes monitoring during the construction, operation and decommissioning phases, a total of about 30 years. These observations are classically based on aerial surveys, requiring specialized naturalist observers onboard of a plane. However, at the era of high definition sensors and big data, recent scientific and technological developments enable to radically improve the cost-effectiveness of such monitoring. The SEMMACAPE project (2019-2023) aims at demonstrating the capacity of aerial HD still imagery, combined with a smart processing software, to automatically inventory marine megafauna. The project is built on a fully integrated scientific and technical content: • An aerial campaign, combining simultaneously the standard visual method and a very high definition digital photography system, was performed over a large sector offshore the western coast of France, in the gulf of Biscay. This campaign included 3 different seasons of year 2020, in order to integrate the seasonal variability of species and environmental conditions. Around 100,000 HD images were collected, during a total of 9 days of overflight. • Two types of algorithms were developed for the automatic processing of aerial photograph, aimed at animal identification and classification: 1/ detection by deep neural (end-to-end) network, moving directly from the global image to bounding boxes; 2/ detection of anomalies by unsupervised deep learning ; • A large dataset of manually annotated targets was compiled, first to improve the detection capacity of the neural network, then to assess the performance of each detection method. The benchmark between visual observation, manual annotation and automatic analysis is based on statistical indicators declined by species or group of species, examining the dependence to environmental conditions (e.g. wind, swell, sunglint, color and transparency of the sea). These indicators include the ratio of false negative/positive targets, identification at the species level, wrong identification, abundance and spatial distribution. For the first time -as long as we are aware today- the results from automated analysis of aerial images are presented and compared to manual analysis and classical on-board observations. Perspectives for the operational monitoring of future floating windfarms are drawn, both in terms of reliability and cost reduction.

Key words: monitoring, megafauna, imagery, machine learning, seabirds

BIRD AND BAT MORTALITY: RESULTS OF A TEN-YEAR STUDY (2014-2023) AT 20 WIND FARMS IN POLAND

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One of the key elements when assessing the environmental impact of wind farms is the mortality of birds and bats. The problem, however, is the lack of Polish up-to-date databases that could be used in forecasting probable impacts for planned farms and determining the significance of impacts for existing ones. The purpose of this study was to estimate the magnitude of bird and bat mortality at wind farms in Poland and to determine the relationship between collision frequency and parameters such as species, time of year, distance from the tower and bird and bat activity during a given period. Mortality analyses were performed for data from 20 wind farms with a total of 186 turbines, located on open agricultural land in Poland. The data were collected in years 2014-2023 in accordance with national guidelines and then analysed using statistical methods. At the surveyed farms, 605 individuals were found: 324 bats (54%) and 281 birds (46%). Among birds, the most frequent victims were the goldcrest Regulus regulus (22%) and lark Alauda arvensis (16%), while among bats, individuals of the genus Pipistrellus spp. (60%) and common noctule Nyctalus noctula (26%). Overall, most birds were killed in March (18%), April (17%) and October (18%), with a peak in the third decade of March. Most bats were killed in August (44%) with a peak in the third decade of that month. Among birds, 94% of victims were found up to 100 m from the tower and 73% were found within 70 m zone. Among bats, 91% of victims were found up to 70 m away. The correlation between recorded bat activity and mortality was 0.57 and between bird abundance and mortality was 0.47 (p=0.001). Generally, the species that were found most often were those common in the country. The results clearly indicate the periods particularly fraught with collision risk for both groups. For birds it was spring migration (March-April) and autumn migration (October), while for bats the time of breakup of the breeding colonies (August). This information will be used to modify methods of mortality studies, especially in terms of verifying the number of inspections during periods with the highest probability of collisions, and to develop a more effective method of searching for victims. The results will also be used to assess the collision risk in accordance to activity of birds and bats at a given location, and plan methods for minimizing negative impacts.
Key words: onshore, birds, bats, mortality

AERIAL PHOTOGRAMMETRY INSIGHTS: ASSESSING COLLISION RISK OF BLACK-LEGGED KITTIWAKES IN THE UK AND IRELAND

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Offshore windfarms are rapidly becoming an important source of renewable energy worldwide. However, the construction and operation of wind turbines can negatively impact wildlife, particularly seabird species whose foraging, commuting and migration co-occur with the offshore infrastructure. Information on seabird flight height is essential in determining collision risk associated with offshore windfarm developments. Current flight height assessment methodologies include the use of GPS loggers, laser rangefinders, LiDAR, and aerial photogrammetry. Due to their conservation status and foraging behaviour, black-legged kittiwakes (Rissa tridactyla, hereafter 'kittiwake') have been identified as one of the species most at risk of collision in the UK and Ireland. We have thus, analysed kittiwake's flight heights using aerial photogrammetry (Humphries et al., 2023) from data collected by HiDef Aerial Surveying Ltd during digital aerial video surveys (DAS). DAS data used for this research were collected during monthly surveys at 13 locations between 2019 and 2022 around the UK and Ireland. A total of 16,191 kittiwake flight heights were measured. Using a theoretical scenario with turbine rotor swept area between 30m and 150m above sea level, it was estimated that, across the UK and Ireland, 34.69% of kittiwakes flew at collision risk heights, while 64.94% and 0.37% flew below and above the blade rotor swept area respectively. No difference in flight height was found between seasons in the northern and southern North Sea, Celtic and Irish Seas. On average, kittiwakes flew higher in the Celtic Sea and lower in the Southern North Sea. Distance to the coast was also investigated and found to have no effect on kittiwakes' flight heights overall or within each region. Results suggest that kittiwakes are at lower collision risk with offshore wind turbines in the UK and Ireland than previously estimated, irrespective of the distance from the coast or region. This aligns with research conducted at Aberdeen Wind Farm, Scotland, where similar, albeit slightly larger, kittiwake flight heights were recorded, with no collisions reported over the 2020/21 breeding seasons. Incorporating DAS methodologies can reduce bias from traditional methods used to measure seabird flight height and distribution and provide site-specific measurements for collision risk assessment with no additional surveying cost. This is essential to inform the siting and design of offshore windfarms to minimise impacts on kittiwakes and other seabird populations, and to guide future research on the ecological consequences of offshore windfarm developments.

Key words: Seabird flight height, collision risk, aerial photogrammetry, offshore windfarm, kittiwake

IDENTIFYING AND STUDYING VULNERABILITY OF MIGRANT LAND BIRDS FOR OFFSHORE WIND FARMS

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Within the Dutch 'Wozep' programme, focused on ecological effects of offshore wind farms, most of the attention given to birds has so far been spent on the typical species of marine and coastal environments as well as on the diurnal flight behaviour of these birds. Nonetheless, it has been obvious from the very beginning that migratory 'land' birds might also suffer losses while travelling over sea on their twice a year migration routes between their breeding areas and their wintering quarters. Moreover, quite a high proportion of migratory non-seabirds are notorious nocturnal migrants and may thus be more vulnerable to e.g. collisions with both offshore and onshore turbines in wind farms than diurnal migrants. In this presentation we strive at outlining the approach we now propose for studying the effects of offshore wind farms on migrant birds in the Netherlands until 2030. Due to the complexity of the subject, we are interested to discuss with other regulators and scientists on how they would approach this subject. We suggest to follow a stepwise approach, aimed successively at 1) identifying the most abundant species of migrant land birds likely to be involved in fluxes passing through offshore wind farms, 2) assessing their actual vulnerability to additional collision-induced annual mortality in relationship with their most likely migration routes and their population status and 3) identifying possible and promising ways of really investigate relevant details on their migration routes and vulnerabilities by means of more detailed observations at sea (radar, visual observations, (night) cameras and/or sound recordings) and of telemetry studies and 4) identifying and testing possibilities for mitigation.

Key words: Migratory birds, collisions, offshore wind

DATABASE OF RESEARCH GAPS FOR UNDERSTANDING EFFECTS TO WILDLIFE AND THE ENVIRONMENT FROM OFFSHORE WIND ENERGY DEVELOPMENT IN THE U.S. ATLANTIC

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Offshore wind energy development is a rapidly growing industry in the United States. To inform our understanding of wildlife populations and ecosystems, and to be able to detect changes in these systems as a result of offshore wind energy development, research must be conducted at a range of spatial and temporal scales. Coordination of these efforts will be required to inform our understanding of offshore wind effects, and in particular the potential consequences and cumulative impacts of these effects on wildlife populations and their habitat. The Offshore Wind Environmental Technical Working Group, a stakeholder advisory group led by New York State, and the U.S. Department of Energy determined that guidance was needed to ensure that regional research to understand wildlife and ecosystem effects of offshore wind development is conducted efficiently and effectively. A regional synthesis workgroup, made up of independent scientific experts, was formed to meet this need and develop the U.S. Atlantic Offshore Wind Environmental Research Recommendations Database (https://tethys.pnnl.gov/atlantic-offshore-wind-environmental-research-recommendations). This database, hosted on Tethys, compiles and synthesizes data gaps and research needs from a range of sources published between 2015-2021 (n=47). This effort resulted in a synthesized list of 219 research recommendations focused on topics such as baseline wildlife abundance and distributions, effects on a variety of environmental receptors, cumulative impacts and population dynamics, and technological and methodological development needs. Users can easily access, sort, and prioritize research needs in the database. A similar effort was undertaken for the U.S. Pacific Coast to develop a sister database of research needs, which is also hosted on Tethys. Potential end users of these databases include government entities who are funding regional research in the next 1-3 years, offshore wind developers who are funding regional research and monitoring efforts, and regional research entities. The U.S. Atlantic database is accompanied by a guidance document with recommendations for conducting regional research, which is expected to be finalized in summer 2023. Synthesis of research questions and data gaps, and development of guidance for studies that require regional-scale efforts, will help to inform funding allocations and other decisions around research and monitoring for offshore wind development in the coming years.
Key words: Research gaps, wildlife, environment, effects, offshore wind

KNOWLEDGE GAPS OF THE IMPACT ASSESSMENT FOR VERTEBRATE AERIAL FAUNA IN THE GLOBAL DEPLOYMENT OF WIND ENERGY

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Wind farms are becoming more present worldwide as a means of obtaining energy from renewable sources in a more sustainable way. Their implementation, desirable for the energy transition, is not free of impacts on the natural environment. The potential negative effects on wild animal populations, specially bats and birds, must be properly taken into consideration both during the planning and operation phases of the deployments, otherwise these taxa can suffer high mortality rates. The correct mitigation of the impact of wind turbines on bats and birds depends on the proper understanding of their interaction with this fauna. To explore whether there is a relationship between the knowledge of these interactions and the deployment of the world's wind power, 450 publications indexed in the SCI have been analyzed, resulting from searches in the Web of Science aimed at finding any published paper on the impact of terrestrial wind farms on birds and bats populations. The papers have been classified according to: their geographical scope, main topic (impact assessment, mortality estimation methods, mitigation methods), the nature of the data they convey (original or not) and the taxa included, among other factors. A special focus has been placed on the papers dealing with the factors that allow for the accurate estimation of mortality, namely detectability of the carcasses and search efficiency. Regions with knowledge gaps that need to be bridged through more research have been identified. A disparity has been found between the development of wind power and the development of knowledge about the impact and fatality estimation methods on bird and bat populations. The review reveals the scant use of detection dogs for fatality searches despite their higher performance and consequent reliability when estimating mortality rates; standardized protocols for the use of detection dogs are needed. More efforts should be devoted to understanding the impact and appropriate mitigation measures, especially in regions where there is more development in wind energy production.
Key words: environmental impact, wind power, bats, birds, knowledge gaps

METHODS TO ESTIMATE COLLISION RISK AND BEHAVIOURAL REPONSES OF SEABIRDS AROUND WIND TURBINES IN THE FIRTH OF FORTH

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The development of wind energy is crucial for mitigating the impacts of climate change. Offshore wind farms are an increasingly used source of renewable energy but there are concerns of their potential effects on wildlife, particularly on seabirds. To address this issue, a comprehensive study has been devised to monitor the impact of the Neart na Gaoithe offshore wind farm, off the east coast of Scotland on two seabird species: northern gannet and black-legged kittiwake. The study will be conducted over a two-year period and will provide a detailed understanding of how these species interact with wind turbines and how they adapt to the changing environment. It will focus on acquiring empirical measures of collision rates and collision risk (micro-avoidance), as well as obtaining three-dimensional records of flight behaviour around wind turbines and the area surrounding the windfarm, to characterize meso- and macro-avoidance responses. A setup comprising three dual radar sets (horizontal and vertical radars), each complemented with two long-range cameras, and six video collision detection systems will be used to monitor the flight patterns of seabirds in the study area, and to detect bird collisions. This technological approach is combined with a strong component of human validation ex situ (for recorded media) and in situ (observers). The use of multiple monitoring systems aims to increase the accuracy and reliability of the data collected, allowing for a more comprehensive assessment of the behavioural responses of the target species. Data obtained from radar will provide estimates of the flux of birds crossing the wind farm to calculate species specific avoidance metrics. The influence of different variables on collision rates will be analysed using a time series approach based on Generalized Additive Modelling. Different models will be fitted considering collision rates estimated for different time resolutions to assess the potential effect of variables acting at different temporal scales. The methodology used to estimate the collision risks and analyse behavioural responses will provide important insights into species-specific responses and behaviour of both target species at the offshore wind farm. Qualitative and quantitative analysis of the statistical methods presented will also help to understand how the quantity and quality of the gathered data affects the statistical significance of the results obtained. The study will help inform the development of future offshore wind projects to minimize impacts on wildlife, particularly those located in proximity to long-term monitored breeding colonies.

Key words: Seabirds, Collision risk, Avoidance behaviour, Wind turbines

TRIALS OF NOVEL METHODS TO DETERMINE THE ORIGIN OF SEABIRDS AT DOGGER BANK A & B OFFSHORE WINDFARMS, UK

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Trials are being undertaken off the north-east coast of England during the summer of 2023 to catch gannets (Morus bassanus) and kittiwakes (Rissa tridactyla) at sea. This is the first phase of implementation of the Ornithological Monitoring Programme (OMP) for the consented Dogger Bank A and B offshore windfarms, which are currently under construction. The OMP proposes novel methods to establish the extent to which the windfarm sites are used by non-breeding and breeding seabirds and (for the latter) their breeding colony origins, with a specific aim to establish the proportion of birds that are associated with Flamborough and Filey Coast Special Protection Area (SPA). This will be used to verify the conclusions of the Habitats Regulations Assessment (HRA) for the windfarms' consent, and improve knowledge of the movements of these species during the breeding season and the apportionment to different colony populations. To our knowledge, catching seabirds at sea has not previously been undertaken for scientific purposes in UK waters, and the trial will test a number of capture techniques to establish the efficacy and viability of these methods. It is proposed that stable isotope sampling and elemental profiling is used to establish the origin of the birds. Again, this is an approach not previously used in seabird research and monitoring in the UK. Feather samples will be collected from captured birds, taken from locations on the bird known to be grown at the breeding colony. Feather samples will be sent for laboratory analysis to determine both the isotope signature and elemental profile. In parallel to this work, it is proposed that feather samples are taken from kittiwakes and guillemots (Uria aalge) at key colonies along the UK North Sea coast, which will be analysed to identify the stable isotope and elemental profile signatures of the colonies. Feather samples will be taken from chicks (and potentially also adult kittiwakes), where possible as part of existing ringing activities. At this stage, the resolution of the signatures it is not known, but it is considered that they may be sufficient to establish the likely colony origin of birds present at the windfarm site. The poster will present the objectives and methods of the above elements of the OMP, together with the preliminary results of catching trials undertaken in summer 2023. It is hoped that updates on this novel work will be provided to future CWW conferences.
Key words: Gannet, kittiwake, stable isotope, catching seabirds

THE USE OF LIDAR TO PROVIDE MORE DEFINITIVE FLIGHT HEIGHTS OF DIFFERENT SEABIRD SPECIES AND GROUPS WITHIN AND OUTSIDE OF OWFS ACROSS DIFFERENT SEASONS AND CONTINENTS TO PROVIDE MORE CERTAINTY WITHIN COLLISION MORTALITY ASSESSMENTS ACROSS THE GLOBE.

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Understanding seabird flight heights and behaviour in and around operational offshore wind farms is a priority knowledge gap. Being able to accurately determine the height at which seabirds fly at and estimating the proportion flying at collision risk height is an integral part of assessing potential collision risk at offshore wind farms (OWFs). APEM Ltd have pioneered the commercial scale use of laser imaging, detection, and ranging (LiDAR) technologies using aircraft mounted systems, which has now been deployed in European and Australasian waters for a number of OWF projects. This includes the use of APEM's bespoke integrated system with LiDAR to detect where a seabird is spatially and high resolution aerial digital stills cameras to provide the identification to species level of each flying bird. Projects have recently been completed for Marine Scotland Science in the UK waters and the Star of the South OWF in Australian waters, whilst others are ongoing for a number of developers in the UK for both baseline data collection and in their post-consent monitoring. This presentation aims to provide a review and demonstration of data collected to date in different visual forms to provide for a clear understanding of the findings for different seabird species to date. This will include 3D models providing viewers with a more interactive experience to understand bird flight behaviour in the marine environment and within and around built offshore wind farms. It will also provide an account of the statistical analysis of data sets undertaken to date and any key findings. The collection of such robust data on seabirds has the power to reduce a number of uncertainties currently assumed when considering different methods of estimating collision risk for different seabird species and species groups. Having confidence in bird flight heights within offshore wind farms provides a key element to reduce the uncertainty in current assessment methods whether being incorporated into collision models or individual based modelling methods used to estimate mortality rates when undertaking impact assessments. This presentation could equally be presented at CWW as well as being the topic of workshop to help encourage wider collaboration on the different approaches on how best to collect and utilise such data sets in the future for impact assessments.

Key words: LiDAR, seabirds, collisions, flight heights

ALTITUDE-SPECIFIC FORECASTS OF BIRD MIGRATION FOR WIND CURTAILMENT

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In the Netherlands, wind curtailment is being implemented to avoid bird collisions not only at the level of individual turbines but also of entire wind parks. To reduce the societal impact of these aeroconservation measures at this massive scale, accurate and timely forecasts of bird migration have to be used to increase the conservation benefits while lowering the societal costs. Networks of weather radars enable us to continuously monitor the migratory movements of flying animals, and their measurements can thus be used to further our understanding of and to help predict the mostly nocturnal migratory movements of billions of birds. In recent years, statistical and machine learning methods, fitted with data from weather radars, have been used successfully to forecast bird migration and to reduce human-wildlife conflicts, e.g. by curtailing wind or switching off lights to avoid building collisions. Here, we present a novel modelling framework combining statistical/machine learning approaches with simulations from individual-based models. This combined approach is used to improve migration forecasts by using better estimates of weather conditions experienced by migrants while flying in the vicinity of the radar, en-route and on their stop-over sites. We use this new framework to forecast altitude-specific bird migration densities tailored to requirements of wind curtailment, specifically low-altitude migration. We address the performance of this new modelling framework model at predicting migration peaks and show some of the underlying weather conditions shaping pulses of bird migration.

Key words: migration, forecast, wind curtailment, weather radar, altitude

IMPROVING THE UNDERSTANDING OF KITTIWAKE NESTING PATTERNS IN THE SOUTHERN NORTH SEA TO INFORM THE DESIGN OF APPROPRIATE COMPENSATION MEASURES

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Goal: Offshore wind farms are key in the efforts to mitigate the impacts of climate change. However, with increasing pressures on seabirds there is a growing risk of significant adverse effects on protected sites. Orsted has been at the forefront of developing compensation workstreams. The Hornsea Four project is required to compensate for the potential impact to kittiwake Rissa tridactyla from collision with the operational turbines of the windfarm. After investigating potential options, the provision of an offshore artificial nest site was identified to be carried forward as a compensation measure. To support this, more information on the nesting habitat, spatial distribution and use of existing offshore structures by kittiwake within the UK southern North Sea (SNS) was required to help inform site selection and future design principles. Material and methods: • Extensive engagement with oil and gas operators in the SNS to begin to document the absence or presence of nesting kittiwake on specific platforms and inform the scope of a targeted survey campaign. This was the first attempt in recent years to characterise breeding seabird presence on offshore assets. • Vessel based bird surveys undertaken in June-July 2021 and 2022 around a number of offshore installations in the SNS region. The surveys recorded information on colony presence and size, population growth rates and breeding success. • Aerial surveys in July 2021 and 2022 undertaken to supplement vessel-based results to enable nesting information to be obtained for additional platforms. Results: Kittiwake were observed readily utilising a number of oil and gas platforms. The repeat surveys in 2022 recorded increased numbers at many of the colonies compared to 2021. Spatial patterns of nesting concentrations within the SNS were identified and used to inform the site selection for a new offshore nesting structure to maximise colonisation potential. A suitable option for repurposing an existing gas platform to a seabird nesting structure was identified. Breeding razorbill and guillemot, in lesser numbers than kittiwake, were also recorded during the 2022 vessel-based surveys. Conclusion: It is considered that the establishment of an offshore artificial nest site would provide a viable and effective compensation option. As a result of this work, two viable options for delivering an offshore nesting structure for kittiwake were identified; an ecologically suitable location for a new offshore structure and a suitable platform to repurpose with an established kittiwake colony. There is wider potential for offshore wind seabird mitigation and compensation to benefit from working across industries.

Key words: Kittiwake, Compensation, Artificial Nesting

WIND FARM DEVELOPMENT AND MITIGATION MEASURES IN A SINGLE WOLF PACK IN PORTUGA: INSIGHTS FROM LONG-TERM MONITORING

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In Portugal, Iberian wolves are protected and classified as endangered. Therefore, National environmental authorities determine that wind farms planned to be established within the wolf's range and which are required to conduct an environmental impact assessment (depending on location and size of each wind energy project), usually need to implement mitigation measures focusing this species. Subsequently, over the last two decades several mitigation measures focusing wolves for wind farm development have been implemented throughout the species range and, frequently, even inside the territory of a single pack. This is the case of the Leomil pack, included in the small and threatened subpopulation located south of Douro River (central Portugal), estimated in only six packs, apparently isolated from the remaining Iberian wolf range. This pack's territory is not covered by a protected area, although the Leomil pack is considered crucial for the conservation of this population nucleus, due to higher breeding rate and pack size. Nevertheless, six wind farms have been sequentially implemented inside the pack's territory since 2006. These currently comprise a total of 114 wind turbines (WT), of which, only 2 wind farms (61 WT) were subjected to an environmental impact assessment and required to implement several mitigation measures. As a result, the Leomil pack is a relevant case study to address the implementation and efficiency of the mitigation hierarchy applied to a large-sized mammal. In this presentation, we describe the design and implementation of several types of mitigation measures (avoidance, minimization, and compensation) for each wind farm built inside the Leomil pack´s territory as well as the effects on wolves based on continuous wolf monitoring resorting to a multi-method approach. Furthermore, the long-term wolf monitoring plan enables us to adjust and/or propose new mitigation measures, when necessary. Based on our findings, we explore the positive and negative outcomes, lessons learned, as well as future challenges, given the increase in construction of infrastructures, such as wind farm overpowering and solar power plants. Impacts of wind energy development on terrestrial mammals, like wolves, are often neglected. Although nonfatal effects such as disturbance or displacement are difficult to evaluate, this case study provides a practical example on how to implement and assess the mitigation hierarchy for infrastructure development.

Key words: wolf, onshore, mitigation measures

BATS NEED CLEAN ENERGY, TOO: DESIGNING SMART CURTAILMENT ALGORITHMS WITH CONSERVATION AND CLEAN POWER POTENTIAL

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Bat mortality is an enduring environmental challenge facing the wind energy industry. The climate-related benefits of wind energy for bat populations can only be fully realized if the industry is able to reduce the direct mortality impacts of wind turbines. “Blanket curtailment” – curtailing turbine operations up to a threshold wind speed – is a common practice to reduce bat mortality. Blanket curtailment leads to excessive power production losses without any conservation value (i.e. reduction in risk to bats) during periods of low bat activity. Bat activity is associated with weather conditions such as wind speed and temperature, as well as with calendar date and time of night. Therefore, “smart curtailment” sets curtailment schedules that reflect the conditions of highest risk to bats, optimizing conservation benefits while reducing turbine downtime. However, power production depends strongly on wind speed, so a better solution is to optimize conservation benefits while minimizing lost power production, rather than simply minimizing the amount of time that turbines are curtailed. We introduce an Optimized Smart Curtailment (OSC) model that minimizes lost energy production due to curtailment. Our OSC model is developed in a Bayesian Classification and Regression Tree (CART) framework, and creates a variety of curtailment algorithms informed by time and weather covariates, bat activity, and power production potential. The model produces algorithms that optimize conservation value and power production. We used data from a wind energy facility in the Midwestern United States to develop OSC algorithms and compared the resulting algorithms to 4.5 meter-per-second blanket curtailment. Our OSC model can produce algorithms that reduce risk to bats by up to 35% more than blanket curtailment while holding power production constant, or reduce power losses by up to 50% while holding risk reduction constant. Intermediate algorithms that compromise between risk reduction and power losses are also possible. Flexible curtailment solutions will enable the industry to safeguard vulnerable species and deliver the climate-related benefits of renewable energy.
Key words: bat mitigation, curtailment, smart curtailment, power production

EXPERIENCE FEEDBACK FROM MONITORING THE EFFECTS OF OPERATIONAL OFFSHORE WIND FARMS IN EUROPE - A LARGE-SCALE COMPARISON

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Currently, the expansion of offshore wind energy is accelerating worldwide. As the number and size of turbines increase, so do the environmental impacts, which are not yet fully understood. The impacts of operational offshore wind farms (OWF) are being studied in different countries through a variety of monitoring programmes. However, the exchange of knowledge between countries is not always given. The aim of this study is to provide a comprehensive comparison of the environmental effects and the mitigation and compensation measures of the operational European OWF. For this purpose, a systematic review of the feedback from already operating OWF will be carried out (not including peer-reviewed articles). This study, which will be carried out over a period of one year, is commissioned by the French national observatory of offshore wind farms led by the French Ministry of Energy, Ecology and the Sea, with the support of the French Office of Biodiversity (OFB) and IFREMER. The consortium in charge of this study is composed of Biotope and its partners HiDef Aerial Surveying, BioConsult SH, BRL Ingénierie and the Royal Belgian Institute of Natural Sciences (RBINS). The first step will be a comprehensive inventory of the operational OWF and their main features. For each country, the regulatory framework will be examined, and the responsible authorities and associated observatories will be identified. Next, about 20-30 OWF will be analysed in detail. The selection of these wind farms will be carried out with the help of a strictly defined list of criteria. The aim is to select wind farms whose context is similar to the French one in order to enable the transferability of the results. The methodologies used to monitor the environmental effects of OWF will be identified and the observed effects on marine ecosystems reviewed. On the one hand, these effects will be examined as a pressure/receptor couple, and on the other hand, possible ecosystem and cumulative impacts will be investigated. Furthermore, the measures used for avoidance, reduction and compensation of impacts will be identified and their effectiveness evaluated. Ultimately, the applicability of the studies' findings to the French context will be assessed, with the aim of gaining important insights for future environmental impact assessment and impact management in France. A meta-analysis of OWF, their impacts and mitigation measures has never been carried out on this scale and can provide valuable information for the public and decision-makers.

Key words: offshore wind, monitoring, mitigation, impacts, experience feedback

A 3D MODEL-BASED APPROACH FOR SPATIAL BAT RISK ASSESSMENT FOR WIND FARMS

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Bat collision risk in wind farms is still an issue that is not correctly assessed in environmental impact assessments (EIA). Impact avoidance in pre-construction phase focuses on avoiding placing the turbines in sensitive areas, i.e., areas where bats are prone to collision. To do so, a correct mapping of these areas is important as well as an adequate collision risk assessment. However, the lack of collision risk models that can provide an estimation of the variation of risk of collision at a spatial level does not allow a proper collision risk assessment during this project phase. The main objective of this work is to provide a quantitative assessment based on a model-based method for spatial bat risk assessment that combines the data that is typically collected during EIA assessments (i.e. spatial and temporal acoustic data). The proposed methodological approach is developed for acoustic spatial and temporal bat data recorded on-site. It makes use of data fusion concepts to combine data from two different sources: ground-level acoustic data and risk-height level acoustic data. The approach is a 3-step hierarchical model-based approach assembled into three components: the first component uses spatial point process models combined with distance sampling techniques to determine bat abundance at ground level; the second component is temporal and uses point process models fed with high-resolution temporal data to estimate variations of bat activity at ground and risk-height level; in the third component the spatial and temporal models are linked together to allow predicting bat activity at risk-height in any given location in space and time. This allows to input this data in an existing non-spatial bat collision risk model to estimate the number of collisions per year at any given location. The approach was tested in a wind farm project and used as a case study and as proof-of-concept. The resulting outputs are the estimation of total bat collisions per year, either in a map (each grid yields the total expected bat collisions per grid per year) or per turbine location (if a turbine layout is available). By using this model-based approach, subjectivity and uncertainty in EIA studies can be reduced and bat collision for a given wind farm project can be estimated prior to construction. This allows selecting the best turbine layout in terms of the lowest expected collisions and better inform on mitigation strategies for the post-construction/operation phase if needed.

Key words: CRM, Collision risk, acoustic data, bats

DEVELOPING COST-EFFECTIVE OYSTER RESTORATION TECHNIQUES IN OFFSHORE WINDFARMS - THE ECOSCOUR PROJECT

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European flat oyster (Ostrea edulis) reefs once occupied a vast area in the southern North Sea and played an important ecological role by influencing the local environment and hosting a wide range of species. These reefs have almost completely disappeared as a result of fishing and, later, disease, leading to a soft-bottom environment that is no longer conducive to autonomous regeneration of flat oyster reefs. The construction of offshore wind farms brings with it the introduction of significant volumes of hard substrate and thus provides an opportunity to recreate oyster reefs. The objective of the EcoScour project is to determine the most cost-effective way to actively introduce flat oyster in offshore wind farms in order to initiate the recreation of oyster reefs, at scale. A series of investigations was made into introduction methods and considerations for flat oyster in the offshore environment. A desk study provided insights on the effectiveness of deploying adults versus juvenile oysters or spat, and on deployment methods. Settlement of oyster larvae on mussel shells, granite, and marble was tested and compared in the field. Sensitivity of oyster spat to invasive alien species treatments was tested and compared for a range of spat sizes. Deployment of adult oysters was tested as loose oysters on hard and soft substrates, as well as fixed on hard substrate. Guidelines for selecting source areas, and procurement considerations, for oysters meant for outplacement were developed. An analysis was carried out to determine the optimal outplacement solution considering costs, benefits, practicalities, and risks. Field-testing of the EcoScour concept was carried out at the two-turbine Borssele V wind farm innovation site, over 20 km offshore from the southern coast of the Netherlands. In October 2020, research cages containing different substrates to compare settlement by oysters and by other species were placed directly on the scour protection, and at 40 cm elevation at both turbines. Brood stock structures with 250 fixed adult oysters each were also installed, with the oysters expected to reproduce and thereby function as in situ larvae pumps to initiate oyster reef development. Monitoring is ongoing. This presentation will present an overview of the EcoScour project from inception to the latest monitoring efforts. We show the various research and monitoring activities that have sprouted from the project thus far, and discuss how these contribute to our goal to make eco-friendly scour protection cost-effective and applicable at scale.

Key words: scale, industry, oyster, restoration, offshore

EVIDENCING COMPENSATION MEASURES: A CASE STUDY OF BYCATCH REDUCTION FOR GUILLEMOT AND RAZORBILL IN UK WATERS.

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Offshore wind farms are key in the efforts to mitigate impacts of climate change. However, with increasing pressures on seabirds there is a growing risk of significant adverse effects on protected sites. Orsted has been at the forefront of developing compensation workstreams, including the first UK offshore wind farm project to develop a compensation package, Hornsea Project Three. Additionally, Hornsea Project Four developed the first complete "without prejudice" derogation case for common guillemot (Uria aalge) and razorbill (Alca torda) associated with the Flamborough and Filey Coast (FFC) SPA, with compensatory measures including predator eradication and bycatch reduction. This presentation outlines the process of developing a compensatory measure, using bycatch reduction as a case study. Accidental capture in fishing gear is one of the most significant threats to marine species worldwide. Under the UK marine bird bycatch Plan of Action, guillemot and razorbill were identified as being especially vulnerable, with guillemots accounting for approximately 75% of observed bycatch in static net fisheries. Despite this, monitoring is lacking due to low onboard observer coverage compared to the scale of commercial fishing, with <1% of UK static net vessels monitored by the UK Bycatch Monitoring Programme. Additionally, there are no trialled and tested methods for static net bycatch reduction. To gain further insight into the impacts of an active static net fishery, Orsted completed the largest electronically monitored at-sea bycatch reduction trial for guillemot and razorbill over two winters from 2021 to 2023. Bycatch risk mapping was undertaken comparing UK fishing effort with seabird distributions on a monthly basis. The English Channel was highlighted as a potential "hotspot" for guillemot and razorbill bycatch throughout the winter season, overlapping with wintering birds from UK designated sites including FFC SPA. An extensive review of bycatch reduction technology was undertaken and the Looming Eyes Buoy, an above water deterrent, was selected for a bycatch reduction technology selection phase undertaken by 10 fishers during the winter of 2021/2022 within the English Channel. Following this, over 20 fishers were then signed for the study the following winter, 2022/2023, with results expected summer 2023. The presentation will detail the extensive research undertaken by Hornsea Four, describe the initial results from this large-scale bycatch reduction study and discuss the implications and challenges of developing novel compensation measures. With Hornsea Four expecting consent decision in July 2023, a further update on the deployment of this compensation measure with likely be discussed.

Key words: derogation, compensation, bycatch reduction

SEABIRD USE OF OFFSHORE PLATFORMS AND IMPLICATIONS FOR CONSIDERATION OF NET GAIN

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The scale of offshore wind development required in European waters to meet climate targets, is such that the need for compensation for its impacts is at the fore. However, new UK policy requires offshore developers to now go further and actively enhance biodiversity to deliver overall net gain. Seabird compensation measures have largely focused on predator eradication at colonies but also recreating nesting habitat using artificial structures. There is an abundance of existing infrastructure in the marine environment but how this is used by seabirds is not well understood. Currently only four species of seabird have been recorded nesting on man-made structures offshore. The Offshore Bird Portal is a new, long-term initiative developed for the energy sector that standardises data collection and collates information on how seabirds utilise offshore structures. Multiple oil and gas operators contribute to this dataset with monthly census and opportunistic sightings data. Increasingly renewables developers and associated service providers are also contributing. This initiative is shedding light on the distribution and prevalence of seabirds nesting on offshore structures, with confirmed instances throughout UK waters. As colonial nesters, kittiwakes find offshore platforms attractive and show high site fidelity once a breeding colony is established. Another potential source of data comes from digital aerial ornithology surveys conducted for offshore wind developers. The combination of a ground sample distance of 2cm and the multiple frames per second of each object captured in HiDef digital video surveys enables high species identification rates. The identification process also records bird behaviour, including a category of "sitting on man-made objects". We reviewed HiDef data from 2011-2021 and found 2,412 records of 14 species associated with offshore structures. The most abundant counts were of cormorant (753), kittiwake (352), great black backed gull (271) and herring gull (251). The most recorded categories of man-made objects were oil rigs and wind turbines. The highest counts of birds associated with man-made objects occurred in May, with a second peak in August. There were 177 incidences of "possible nesting" of terns/small gulls. Whilst these data provide some insight into the species associated with man-made objects, recording of this behaviour until now has not been standardised or collated in a single repository. Understanding seabird use of offshore structures is becoming increasingly important in the context of assessing contribution to net gain solutions for both decommissioning of oil and gas installations and the expanding development of offshore renewables.

Key words: net gain, seabirds, infrastructure, data portal, survey

POTENTIAL IMPACTS AND COUNTERMEASURES OF BIRD COLLISION ON SMALL WIND TURBINES IN JAPAN

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The increase in wind energy has caused bird collisions with wind turbines. Although most collisions have been reported in large wind turbines, reports on collisions of endangered bird species with small wind turbines (SWTs) have been recently increasing in Japan. In this study, we assessed the potential impact of SWTs on birds in Japan. First, we compared the flight frequency of a construction area of SWTs before and after its construction and control areas likewise using BACI (Before-After and Control-Impact) method to investigate whether birds avoid SWTs. While the result showed a significant decrease of flight frequency before and after construction, the result also showed no significant differences between the construction and control areas, implying the decrease in flight frequency was due to the annual variation but not construction, and the construction of SWTs has potential collision risk. Next, we clarified the factors affect the increase of collision risk by assuming that increased flight frequency is associated with increased collision risk. We recorded the flight frequency of birds nearby SWTs and clarified the relationship between the number of birds' flights per hour and environmental factors, such as weather information, geographic information, or so on. The results showed that the increase of flight frequency was due to higher wind speeds and the number of flights significantly differed depending on the location of the SWTs for the White-tailed Eagle, which is an endangered species in Japan. The flight frequency of the Slaty-backed Gull, the Japanese near-threatened species, differed depending on the time of day and season, and the location of the SWTs. From these results, we found flight frequency of birds differed depending on the location of the SWT, thus finally, we assessed the relationship between collision risks and geographical information to develop the collision risk map. We recorded the points of birds flying from a driving car and estimated the distribution of birds using the point data and the geographic data. To evaluate the accuracy of the map, a correlation was tested between estimated abundance of birds and actual flight numbers obtained from point census surveys. The result showed the map had sufficient information on the estimation value of the collision risk of birds compared with observed flight frequencies in the point census surveys. Our results can be used for site selection for constructing SWTs to reduce potential risks of bird collision.
Key words: Small Wind Turbines, Bird Collision, Endangered Species

NEW INSIGHTS ABOUT BIRD MIGRATION IN THE GULF OF LIONS – ORNITHOLOGICAL RADAR SURVEYS WITHIN THE MIGRALION PROGRAMME

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The current development of anthropogenic uses of the Gulf of Lions (French Mediterranean Sea), more particularly the planned installation of offshore wind farms, has highlighted the lack of available knowledge on the use of this area by avifauna and chiroptera. Data acquisition is essential to characterise migration flows, flight altitudes and the functionality of marine areas for marine and terrestrial migratory birds as well as bats at the scale of the Gulf. To meet these knowledge challenges, the French Office for Biodiversity (OFB) has launched the MIGRALION programme (2021-2025) to acquire complementary data on the flying fauna of the Gulf of Lions by deploying the most relevant technologies. This programme includes five technical work packages, i.e. (1) bibliographic synthesis of available data on migratory and marine birds and bats; (2) deployment of biologgers on seabirds and migratory terrestrial birds; (3) boat-based observations of marine megafauna, on-board radars and acoustic technology for birds and bats recordings; (4) ornithological radar surveys all along the Gulf of Lions coast; (5) cross-analysis of the different datasets collected. In this poster, we present results obtained from the analysis of one year of data collection by two ornithological radars (work package 4), the first being stationary in the Camargue area (continuous recording), and the second being mounted on a trailer with autonomous energy supply and installed consecutively on seven sites from the Spanish border (Banyuls) to the Eastern part of the Gulf of Lions (Toulon) during spring and fall migration periods. Results provide for the first time a meso-scale view of bird migration over the Gulf of Lions, studied from the coast during day and night, with detailed description of the temporality of bird migratory events, flights altitudes, directions and migration traffic rates.

Key words: Ornithological radar, migration, Gulf of Lions, offshore windfarms, MIGRALION

OYSTER RESTORATION IN WIND FARMS; WILL THEY STAY OR WILL THEY GO?

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Flat oyster (Ostrea edulis) reefs used to be abundant in the North Sea but are now functionally extinct mainly due to destructive fishing practices. Since inside most offshore wind farms bottom trawling is prohibited, these areas have some potential in promoting the recovery of the species. Previous studies have extensively investigated the suitability of wind farm areas for the restoration of flat oysters, by looking into the historical occurrence of the species, habitat characteristics and larval retention or dispersal. For a suitable site, oyster restoration efforts will typically focus on the introduction of either adult oysters or spat on shell (juveniles settled on empty shells). Sometimes also settlement substrate is provided. Oysters and substrate need to remain in place long enough for an oyster reef to start forming. Scale is important. It is cheaper and easier to deploy loose oysters rather than deploying them in cages or other structures, hence deployment of loose oysters can be done at a larger scale. The present study focuses on the stability of loose oysters under hydrodynamic loads. First, laboratory tests were performed in a controlled environment by simulating a range of conditions, including waves, currents and a mobile seabed. From the tests, reference parameters are derived predicting under which conditions oysters would become mobile. Second, timeseries of hydrodynamic conditions at various offshore wind farm sites were generated employing a numerical model. The reference conditions that describe oyster stability and the timeseries of hydrodynamic conditions at various sites were used to indicate in which parts of the North Sea restoration projects can be carried out with loose material and where more stable structures are required. The results indicate that the wave action near the seabed, rather than currents is the main cause of instability of loose oysters and shells. Mobilization of materials varies in duration over a year for different wind farms due to differences in hydrodynamic conditions, i.e., water depth, waves and currents. However, in most locations of the North Sea, both oysters and various types of settlement material are expected to become easily mobile even under milder storm events.

Key words: oyster restoration, offshore wind, hydraulic stability

DEVELOPING A STRATEGY – APPROACHES TO RAT ERADICATION AS COMPENSATION FOR SEABIRDS

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Compensation for seabirds as a result of perceived impacts from offshore wind development is becoming rapidly more important as nations look to boost electricity generation offshore and bolster energy security. Since 2020, project-led seabird compensation (as part of the Habitats Regulations Assessment Derogations stage) has emerged as a requirement for many UK offshore wind projects, particularly in the southern North Sea. This has led developers to develop and deliver initiatives and concepts for seabird compensation, including novel approaches to 'new' compensation species in both known areas and regions of development. Within the UK offshore wind market, it is clear that evidence requirements for ecological compensation are increasing in the short term. As the cumulative pressure from offshore windfarm projects increases, the number of 'like-for-like' species-specific and deliverable compensation measures diminishes rapidly. Strategic compensation is one solution to this, which could potentially offer large-scale and/or Government-led measures to offset impacts from multiple projects. One of the leading options for strategic compensation in the UK is invasive mammalian predator eradication from seabird colonies. Invasive species eradications aren't a new concept for seabird conservation, with many successful projects undertaken globally. However, their inclusion as compensation means they should ideally be targeted at species adversely affected over the lifetime of an offshore windfarm, and must stand up to the rigours of guidance and stakeholder scrutiny and provide government decision makers with sufficient security that the coherence of the UK National Site Network is ensured (formerly UK portion of the Natura 2000 network). This presentation will discuss the successes, challenges, and future opportunities associated with the UK's first proposed predator eradication scheme (Hornsea Four Offshore Wind Farm) as compensation for offshore windfarm impacts. It will set out the approach to gathering evidence on specific seabird species, quantifying scale of delivery, determining success and how this will be monitored to align with Development Consent Order requirements. This presentation will also discuss how lessons learned first-hand can inform the rapidly developing and vitally needed strategic approach to delivering compensation. This experience provides a robust framework on which to develop a joined up, multi developer, and ultimately strategic approach to delivering compensation while enabling 2050 UK energy targets to be reached, with applicability to other countries solving similar issues. Fraser Carter and the wider NIRAS team, have been at the forefront of seabird compensation and provide a compelling insight of lessons learnt to wider industry to encourage harmony across development and ornithology.

Key words: Compensation, eradication, seabirds, offshore wind

METHODS FOR MONITORING LARGE CARNIVORES IN WIND FARM IMPACT ASSESSMENTS

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Since 2016, when the "Technical manual for the assessment of project impact on large carnivores either individually or within planning documents - example windfarms" was published, monitoring of large carnivores has been carried out in Croatia to assess their use of habitats where the construction of a wind farm (WF) is planned. Besides searching the area and recording the observed signs of large carnivore presence (faeces, footprints, etc.), the basic method proposed in the manual is the camera trap method. When applied in the assumed zone of influence of each wind turbine, the camera trap method gives good results, but also has its limitations: 1) due to the small field of view, numerous camera traps are required to monitor the entire area; 2) camera traps can be used to assess the frequency of habitat use by large carnivores, but not how they use it; 3) it is not possible to determine the exact location of the den, only possibly the existence of reproduction if juveniles are recorded; 4) camera traps cannot be set up in inaccessible and mined areas. The GPS telemetry method provides results on the frequency and type of habitat used by large carnivores, it can provide the exact location of the den, making this method the most effective of all conventional methods. However, the negative side of this method is that it is organisationally and financially very demanding and sometimes uncertain because it is not possible to predict how much time will be needed to capture the animals, i.e. whether the animals can be captured and tracked in the time allotted for monitoring or whether they can be tracked long enough. Furthermore, the marked animal could be killed. In Croatia, the method of recording with a thermal imaging drone has begun to be used experimentally. This method serves as a supplement to camera traps in mined or otherwise inaccessible areas and as a supplement to the GPS telemetry method (recording the number of cubs near the den, individuals in the pack, ...). For the best possible assessment of space use, a combination of at least two of the above methods should be used when monitoring large carnivores, in some cases even all three methods. The presentation contains examples of the application of the above methods for monitoring large carnivores in order to assess their habitat use in the areas of the planned WFs in Croatia.

Key words: wind farms, large carnivores, monitoring methods, impact assessment

CURRENT AND DEVELOPING WIND ENERGY PROJECTS IN ECOLOGICALLY SENSITIVE AREAS IN GREECE: THE ROLE OF THE NEWLY ESTABLISHED NATURAL ENVIRONMENT AND CLIMATE CHANGE AGENCY

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The Greek National Plan for Energy and Climate, drafted in 2023, raises the National target for the participation of Renewable Energy Sources (RES) in gross energy consumption from 35% (as set in 2019) to 45% by 2030. Regarding power generation, the target for RES is set at 80%, an increase by 19% compared to that of 2019. According to data from the Greek Regulatory Authority for Energy, there are currently 370 operating wind farms with 2802 wind turbines (WTs) in the country, of 4664.46 MW total rated power. Ninety-seven of them (1350.29 MW) are located wholly or partially within 47 Natura 2000 sites (787 WTs in Natura 2000 sites). In addition, 1553 production permits have been issued for wind farms, for a total rated power of 27,4 GW, over one fourth of which are located wholly or partially within Natura 2000 sites. The Natural Environment and Climate Change Agency (NECCA) constitutes the main coordinating body of the newly formed Protected Area governance scheme in Greece. Established in 2020 and operating under the supervision of the Ministry of Environment and Energy, NECCA's key responsibilities include providing its opinion on the Appropriate Assessment for projects and activities that may have implications on Natura 2000 sites, under Article 6.3 of the 92/43/EU Directive. In 2022, NECCA received 109 applications for windfarms, of approximately 3,8 GW total power, that were located within Natura 2000 sites or in adjacent areas. For 33,5% of the applied total rated power (ca 1,3 GW) the response was positive, under the condition that specific mitigation measures would be implemented. For the rest of the projects, impacts were assessed as too significant to allow for a positive opinion. NECCA is developing tools for facilitating the licensing process, including a national biodiversity database (under LIFE EL-BIOS project), so that data are available to all interested stakeholders, a Web-GIS based decision support system (under LIFE-IP 4 NATURA project) addressed to all the authorities involved in the licensing process, as well as country-level sensitivity maps. To further facilitate and speed up environmental licensing processes for wind farms, relevant national legislation requires reforms. These should include a clearer incorporation of EU Directives and provision of precise definitions and specifications on matters such as project fragmentation, cumulative effect assessment, definition of alternative solutions, designation of appropriate study areas and application of appropriate per case sampling methods and timeframes for the Appropriate Assessment.

Key words: protected areas, appropriate assessment, opinion, project licencing

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