



# Conference on Wind energy and Wildlife impacts

## Book of Abstracts

What have we learnt so far? Which uncertainties remain?  
Where do we go from here? – It is time for an international synopsis!

March 10-12, 2015 in Berlin





# Book of Abstracts

## Conference on Wind energy and Wildlife impacts

Berlin March 10-12, 2015

*Johann Köppel & Eva Schuster (eds.)*

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## Preface

Welcome to the CWW2015 in Berlin!

The Environmental Assessment and Planning Research Group at the Berlin Institute of Technology (TU Berlin) is delighted to welcome you to the Conference on Wind energy and Wildlife impacts (CWW) 2015 in Berlin. Our research group has been involved with wind power and wildlife research for more than a decade. As we have been able to compile a synopsis of research results on wildlife effects from wind power for the Federal Environmental Ministry/the Federal Ministry for Economic Affairs and Energy since 2012, hosting the CWW2015 constitutes a perfect fit with our ongoing synoptical work and an important milestone.

The two previous conferences, CWW in Trondheim (2011) and CWE in Stockholm (2013) have provided excellent opportunities for international exchange on wind energy's wildlife implications and have set high standards. We hope that the CWW2015 can continue this principle; the interest at least has been overwhelming once more. With 162 abstracts submitted, we will be able to share 65 oral presentations in two parallel streams and plenary meetings as well as an additional 54 selected posters will be presented. Approximately 400 delegates have registered, coming from more than 30 countries. Thus, there is seemingly still a large interest and need for international exchange of knowledge on wind energy and wildlife impacts and we are looking forward to these three exciting days.

As a conference of this size involves considerable efforts regarding the organization and budget, we are very grateful for financial support by the German Federal Ministry for Economic Affairs and Energy (BMWi). We would like to thank all who have supported the making of CWW2015 in Berlin, Tobias Verfuß and colleagues at the Projektträger Jülich (PtJ), as well as all staff involved from our working group at TU Berlin. All this would not have been possible without our Scientific Committee whose members we want to thank for their efforts: Dr. Andrew Gill (Cranfield University, UK), Åsa Elmquist (Vindval, Sweden), Dr. Christian Voigt (IZW, Germany), Dr. Cindy Hull (University of Tasmania, Australia), Dr. Edward B. Arnett (TRCP, USA), Dr. Jan Olof Helldin (Calluna AB, Sweden), Dr. Marc Reichenbach (ARSU GmbH, Germany), Dr. Meike Scheidat (IMARES Wageningen UR, The Netherlands), Dr. Michelle Portman (Israel Institute of Technology), Dr. Ommo Hüppop (Institute for Avian Research, Germany), Dr. Roel May (NINA, Norway), Dr. Rowena Langston (RSPB, United Kingdom), Dr. Shawn Smallwood (USA) and Dr. Johann Köppel (Berlin Institute of Technology, Germany; Chairman). Furthermore, we like to thank our further keynote speaker Dr. Kjetil Bevanger (Norwegian Institute for Nature Research, Norway) and all session conveners. Special thanks go to all speakers and poster presenters for their contributions to the conference. Tobias Verfuß and Eva Schuster served as reviewers for the best poster award. Lastly, we would like to give special gratitude to Eva Schuster for her unmeasurable work and leadership regarding all conference organization responsibilities.

We wish you all a great and rewarding conference and are looking forward to future events to come!

Berlin, March 2015



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# Keynotes



## A global perspective on bats and wind energy development

**Edward B. Arnett**

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Developing renewable energy alternatives has become a global priority, owing to long-term environmental impacts from use of fossil fuels, coupled with a changing climate. Wind energy continues to be one of the fastest growing renewable energy sources under development and while representing a clean energy source, it is not environmentally neutral. Large numbers of bats are being killed at utility-scale wind energy facilities worldwide, raising concern about cumulative impacts of wind energy development on bat populations. In this presentation, I will discuss a recent synthesize of information on bat fatalities at wind energy facilities worldwide and discuss estimates of fatalities, unifying patterns and themes, and policy and conservation implications. I will also offer insights for future directions of research and mitigation of bat fatalities at wind facilities. Given the magnitude and extent of fatalities of bats worldwide, the conservation implications of understanding and mitigating bat fatalities at wind energy facilities is critically important and should be proactive and based on science rather than being reactive and arbitrary.

## Facts on bird collisions with power lines – have we taken it on board to understand and mitigate bird wind-turbine conflicts?

### **Kjetil Bevanger**

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Overhead wires were among the first air obstacles reported to kill birds, close to 150 years ago. Over time, the number of bird deaths and the quantity of air wires have increased dramatically. About 40 years ago, the bird power-line conflict became more systematically addressed in several countries, and the first publications on the issue were born. Some 20 years later the first publications on birds and wind-turbine conflicts appeared. After that, the literature on the topic has become extensive. It is interesting to notice that a majority of the publications dealing with wind turbines and birds have few citations from research on birds and power lines, as long as the conflicts have several common elements. Several aspects of avian interactions with air wires can be used to understand, and mitigate, problems connected to birds and wind turbines. Over time, several review papers and state of the art reports have been published on bird power-line conflicts, thus existing knowledge should be easily accessible. What are the similarities and dissimilarities when it comes to problems related to birds, power lines, and wind power generation? A main and early conclusion is that the problems are highly species-, site- and seasonal specific, and that most aspects are inappropriate for broad generalisations and standardised research methods. The same applies to birds and wind turbines. The biological characteristics of a bird species, interactions with other faunal and vegetation elements, topography and meteorological conditions are all among several factors easily influencing the results of a study. An obvious conclusion is that to achieve progress in understanding these complex conflicts a close cooperation across professional disciplines, i.e. biology, ecology and differing engineering disciplines is vital.

## Filling gaps in understanding ecologically relevant interactions between marine animals and offshore wind developments

### Andrew B. Gill

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Understanding of interactions between marine animals and offshore wind energy developments continues to grow, however, the knowledge base varies widely. Consequently, the determination of what constitutes an environmental interaction that may require mitigation or what environmental monitoring is appropriate can have a large degree of uncertainty associated with it. This presents problems both for those involved in harnessing the offshore wind resource and those guiding and licensing offshore wind developments. Differing opinions exist on what should be the focus of our studies and currently most activity is driven by the existing environmental legislation. Hence, some aspects are relatively well studied (e.g. bird behaviour around wind turbines) but others are not (e.g. seabed community change). Gaps in understanding manifest themselves within our environmental assessments via generic considerations of an interaction, whereas more specific elements considered tend to be associated with greater amount of knowledge. Poor knowledge results in an unbalanced and subjective environmental assessment and low confidence leading to a precautionary approach within the associated guidance and decision making. Taken together we have some key aspects that are the focus of existing studies mainly driven by the environmental legislation but significant gaps with a high level of uncertainty remain. Looking forward we will have to redress this imbalance as legislative drivers have become more integrated and ecosystem focused.

As a step forward in acknowledging and addressing the identified issue, I discuss recent international collaborative research that focuses on key questions concerning ecologically relevant consequences. These questions have a lot of uncertainty associated with them and have a raised profile via recent environmental legislation. The main example I use is the emission of energy into the marine environment in the form of underwater noise emitted by offshore wind construction and operation and the potential influence of electromagnetic fields (EMF) associated with the cables transporting the electricity generated. In Europe, energy emissions have to be considered under the EU Marine Strategy Framework Directive, but there is very restricted knowledge on which to try to answer questions about their impact (or not) on animal receptors. The second example highlights outputs from international working groups focused on understanding changes to benthic communities and consideration of their ecosystem service. These examples are used as questions are raised about them but are often dismissed, principally because of a lack of knowledge, however, the questions continue to come up owing to the large degree of uncertainty. If knowledge gaps were reduced through appropriately targeted knowledge improvement then confidence will rise in our understanding of offshore wind development interactions with the marine environment.

## What we (should) know about offshore bird migration

**Ommo Hüppop**

Institute of Avian Research "Vogelwarte Helgoland", Wilhelmshaven/Germany

Migration is a worldwide year-round phenomenon in the annual cycle of most bird species. Mobile organisms can leave areas with (seasonally) deteriorating resources and move to regions with better food, nesting sites or other essential supplies. It is estimated that 50 billion birds annually move between their breeding, moulting and wintering areas. Only very few bird species are strictly sedentary. However, depending on species, season, location, weather and distances to be covered, migration intensity, direction, flight speed and altitude vary considerably, sometimes even within a few hours.

While waterbirds - namely marine ones - try to avoid crossing large land masses, land birds are more or less reluctant to fly larger distances over sea. Nevertheless, crossing these kinds of ecological barriers rather than circumventing them can reduce flight costs and time considerably, especially when birds can fly with the assistance of tailwinds. Thus, despite the risks associated with flights over water, not only waterbirds move far away from land when on migration. The 'champions' fly nonstop nine days more than 11,000 km over the open ocean! Many species that are normally diurnal become more or less nocturnal during their migration flights. Roughly two thirds of the European bird species migrate mainly or exclusively during the night.

Onshore, birds are known to collide with wind turbines, some species more than others, but with a few exceptions in numbers that seemingly do not threaten populations. Offshore, the situation might be different. Virtually we have no clue about numbers of collision victims at offshore wind farms since carcass collection at sea is impossible and other methods to quantify bird strikes with wind turbines still need to be improved considerably. Collision models suffer from uncertainties in estimates of avoidance (or attraction) rates. Actually, numbers of collision victims might be higher offshore than onshore. Over land birds can interrupt their flight when they get drifted by unexpected winds or lose orientation in deteriorating visibility. Offshore 'landing' would be fatal. Instead birds reduce flight altitude and during darkness they are attracted by illuminated structures where they 'hope' to find a place for landing. Wind turbines have lights both for shipping and aviation safety and one can assume that namely the steady ones attract birds under certain fairly rare circumstances in sometimes great numbers. Changing kind and blinking regime of safety lights seem to be an adequate mitigation measure.

Normally the majority of birds are able to recognize wind turbines and other offshore structures. Radar studies have shown that at least flying ducks, geese and swans normally avoid wind farms. However, when they fly at low altitudes (e.g. under head winds) the resulting detours could increase flight costs considerably, especially, if birds cannot detect sufficiently broad gaps between wind farms.

Last but not least, possible impacts of offshore wind farms on bird populations are extremely difficult to predict and depend on – besides collision rates and energetic constraints – the complex life history of the species.

## Wind energy down under: what have we learnt?

**Cindy L. Hull**

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Australia's unique fauna has arisen due to the geological development and isolation of the continent from other landmasses for millions of years, resulting in a high level of endemism. Convergent evolution between Australian species and those from other continents occurred, meaning many Australian species occupy the same niches as elsewhere. There are no large-scale bird or bat migrations across the continent, therefore some of the wind and wildlife issues in Australia are different to those in Europe and the Americas. The wind industry is relatively new in Australia, with the first commercial-scale wind farm approved in 2000. All commercial-scale wind farms are onshore and use modern monopole turbines that are widely spaced.

I report on the key findings of 14 years of studies at the Bluff Point and Studland Bay Wind Farms in Tasmania. Bird and bat collisions were monitored for over ten years, and revealed that only approximately 20% of the avian species present on site were involved in collisions, indicating that being on site was not a key risk factor, nor was abundance. Rather, specific families with particular morphological, ecological and behavioral characteristics were more likely to collide. Similar specific characteristics were found for bats, with only tree roosting, high-flying species that foraged in open areas found to have collided. As with overseas studies, bat collisions were highly seasonal, occurring predominantly during autumn.

We documented the avoidance rates of two species of eagle using observational studies, and found that the rates varied between species and sites, although the sites were only 3 km apart. They also varied with the developmental stage of the wind farm, and whether turbines were stationary or moving. Wedge-tailed Eagles demonstrated higher avoidance rates in poor weather. These findings indicated that the interaction of eagles with turbines was complex and suggested that these species had an awareness of the changing risk of turbines and adjusted their behavior accordingly.

Ten years of bird utilization studies examined effects of the wind farms on species diversity and density, resulting in a large quantum of data. However, the ability to draw meaningful conclusions was hindered because we could not differentiate wind farm impacts from larger landscape impacts and other confounding variables, and therefore demonstrate causation for declines. Studies of disturbance effects are problematic due to inconsistent definition of terms, a lack of consideration of effects versus negative impacts, and attention to the spatial scale and biological significance of impacts.

Arguably one of our most important achievements was the development of a functional approach to adaptive management. We developed a collaborative, structured risk assessment, using an evidence-based approach to prioritize the taxa and key risks on site, and then to evaluate the effectiveness of our studies and management actions in light of this. The process enabled us to identify which actions were not adequately targeting key issues, which should cease, be modified or if new actions should be developed.

Renewable energy is currently stalled in Australia due to a lack of political commitment to action on climate change, meaning little research is currently occurring on wind farms and wildlife. Priorities when it recommences are rigorous scientific approaches in monitoring and adaptive management frameworks to evaluate the effectiveness of actions and better target those that are ineffective.

## What have we learned so far? A synoptical perspective on wind energy's wildlife implications

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The recent decade has seen vivid research endeavors and a manifold of results for wind energy's wildlife implications. The CWW2011 and CWE2013 conferences provided valuable hubs for an international exchange and contributed substantially to narrowing down the science-policy gap at hand. Relevant information and best available science must be familiar to decision-makers and society. This is why our CWW2015 mission statement has been dedicated to synoptical efforts.

We have recently contributed to the body of (more sectoral) reviews, evaluating what we have learned on wind energy's wildlife implications, and also which cases we are still facing with arbitrary or differently interpreted research outcomes (Schuster et al., resubmitted<sup>1</sup>). This review provides a qualitative analysis of the main effects of wind energy development on- and offshore, focusing on frequently studied species groups (bats, breeding and resting birds, raptors, migratory birds, marine mammals). Predominant hypotheses have been identified and displayed in tables. For some hypotheses, a substantial consensus has been reached (e.g. correlation between bat activity and environmental factors). Factors influencing effects were mainly related to species characteristics (morphology, phenology, abundance, behavior, and response to turbines) and site characteristics (landscape features, weather, and habitat quality). Research focusing on offshore wind energy has increased significantly as well, catching up with the vast amount of onshore studies. Yet, while manifold studies were established along pioneer offshore wind farms, any up-scaling in terms of the large offshore facilities further planned remains a challenge ahead. Another discourse constitutes the promise of offshore wind farms serving as artificial reefs.

However, the quantification of effects remains challenging, as well as the significance on population levels and the efficacy of mitigation measures. Uncertainties will always persist and thus calls for more adaptive planning and mitigation approaches (Köppel et al. 2014<sup>2</sup>). Based on the findings so far, a comprehensive variety of mitigation measures has been identified and implemented (cf. May et al. 2015<sup>3</sup>), comprising of macro-avoidance, micro-siting, wind facility design, curtailment, decreasing on-site habitat attractiveness, deterrence, but also compensatory mitigation approaches. Promising mitigation measures offshore have been explored too, even noise mitigation from pile driving below critical thresholds has been demonstrated. Fundamental environmental impact assessment and planning approaches have also been elaborated (e.g. mac-

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<sup>1</sup> Schuster, E., Bulling, L., Köppel, J. (resubmitted): Consolidating the state of knowledge – a synoptical review of wind energy's wildlife effects. *Environmental Management*.

<sup>2</sup> Köppel, J., Dahmen, M., Helfrich, J., Schuster, E., Bulling, L. (2014): Cautious but Committed: Moving Toward Adaptive Planning and Operation Strategies for Renewable Energy's Wildlife Implications. *Environmental Management*, 54 (4): 744–755

<sup>3</sup> May, R., Reitan, O., Bevanger, K., Lorentsen, S.-H., Nygard, T. (2015): Mitigating wind-turbine induced avian mortality: Sensory, aerodynamic and cognitive constraints and options. *Renewable and Sustainable Energy Reviews* 42: 170-181.

ro-siting with zoning maps, integrated conservation approaches and adaptive management; Gartman et al. 2014<sup>4</sup>).

Yet the applicability and practicability of mitigation measures have also been challenged, as far as cost benefit analyses might matter, for example. Small-scale and detailed mitigation concepts require the involvement of numerous stakeholders, and concerns on the liability of such micro-mitigation schemes have been raised as well. Novel mitigation measures as the ultrasonic deterrence of bats from wind turbines might lack acceptance in practice. Consequently, using a combination of measures along the whole range of the mitigation sequence, from macro- to micro-and if possible compensatory mitigation, might constitute the only feasible option when spatial resources are limited.

Moreover, while more ambitious approaches for collision risk modelling might become useful decision-making tools, any model remains only as good as the data sets on which it can be based on, especially when individual takes have to be calculated. Missing mortality thresholds still to be elaborated and accepted remain a respective dispute. Adaptive management approaches have partly been established to cope with remaining uncertainties and to allow for monitoring-based adjustments of foremost curtailments in favor of bats. The acceptance of adaptive approaches has been hampered simultaneously, be it due to revenue losses or due to missing transparency as monitoring data may not happen to be disclosed. As Voigt et al. (2015)<sup>5</sup> have pinpointed too, that as long as original data from (pre- and) post-construction surveys are not revealed for meta-analyses, we will lose further time for shaping tradeoffs between renewable energy and biodiversity conservation goals.

Obviously, neglected research requirements involve a fundamental understanding of the effects of repowering. Research addressing the cumulative effects of wind energy and its inevitable expansion of transmission systems still lies ahead as well. The expansion of wind energy within forests has rapidly settled in, while respective empirical studies remain scarce. Offshore, the implications of decommissioning will reveal further challenges ahead. Finally, it is rather safe to state that we are still facing the threat of a substantial “lock-in”, with fossil advocacy coalitions succeeding again (as of coal, natural gas, fracking, carbon capture and storage). Thus, building cooperative stakeholder coalitions both with wind industry and wildlife conservationists matters substantially.

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<sup>4</sup> Gartman, V., Wichmann, K., Bulling, L. E., Huesca-Pérez, M. E., Köppel, J. (2014): Wind of change or wind of challenges: Implementation factors regarding wind energy development, an international perspective. AIMS Energy 2 (4): 485–504.

<sup>5</sup> Voigt, C.C., Lehnert, L.S., Petersons, G., Adorf, F., Bach, L. (2015): Wildlife and renewable energy: German politics cross migratory bats. Eur J Wildl Res, DOI 10.1007/s10344-015-0903-y

## Avoid being trapped: Theoretical foundations for avian responses to wind turbines

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The evidence of bird mortality due to large-scale wind energy development necessitates the identification of the proximate and ultimate causes behind behavioural responses in birds to the impacts wind-power plants and the turbines therein pose them. Here I review the theoretical foundations that shape the wind-turbine avoidance process. To provide a better basis for and improved understanding of the underlying mechanisms for wind-turbine avoidance a conceptual framework is presented. In practice it may be difficult to tease apart different avoidance-related decisions as they may shift gradually into one another. To decompose the concept of avoidance, however, a distinction between different avoidance responses along this continuum needs to be made. The movement ecology paradigm identifies four interacting mechanistic components central to movement: internal state, motion and navigation capacities, and external factors affecting movement. Employing this conceptual framework enables the decomposition of various forms of avoidance at different spatial scales, and links these to fundamental ecological paradigms. For understanding why particular responses occur with regard to wind-turbine disturbance this concept is subsequently applied to the predation risk theory. The risk-disturbance hypothesis postulates that nonlethal disturbance stimuli caused by humans are analogous to predation risk. Evolutionarily, prey have evolved anti-predator responses to generalized threatening stimuli such as loud noise and rapidly approaching objects, and consequently, this approach might be especially useful since responses to predation risk and disturbance stimuli divert time and energy from other fitness-enhancing activities. Wind turbines may be characterized as sources of disturbance stimuli which are being approached, and applied to the concept of avoidance to formalize specific predictions with respect to flight, activity budgets and habitat selection. The ecological trap theory may help understand maladaptive habitat selection with regard to wind energy development. Sudden environmental change may uncouple the cues that individuals use to assess habitat quality (yielding lower fitness) from the true quality of the environment. Ecological traps may occur when animals are falsely attracted to habitats with reduced survival and reproduction. Conversely, perceptual traps may occur when high-quality habitats are avoided when perceived to be less attractive. Dependent on a species' sensitivity to disturbance and vulnerability to collision mortality, this may lead to either selection of risky habitat (i.e. ecological trap) or avoidance of good habitat (i.e. perceptual trap) within wind-power plants. Based on predictions derived from these theoretical foundations, recommendations are given for modelling avoidance components. Formalizing the different forms of avoidance facilitates design of impact studies, enhances comparisons among sites studied, and guide siting and mitigation strategies.

## The challenges of repowering

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Industrial wind power expanded rapidly since the earliest projects, and with this rapid expansion came understanding of wind power's impacts on wildlife and how to measure and predict those impacts. Many of the earliest wind turbines began exceeding their operational lifespans >10 years ago, spawning plans for repowering with modern turbines. All wind turbines eventually wear out. Repowering can replace old turbines that have deteriorated to capacity factors as low as 4% to 12% with new wind turbines with capacity factors of 30% to 38%, and possibly sometimes better. At the same rated capacity, a repowered project can double and triple the energy generated from the project, and 10 years ago I predicted and have since verified that repowering could reduce avian fatality rates by 80-90% in one wind resource area. Repowering often moves electric distribution lines from above to below ground, thus reducing electrocutions and line collisions. It can reduce the number of wind turbines in a project, thereby opening safe airspace to volant wildlife, and it provides opportunity to more carefully site new turbines to minimize collision risk, e.g., by avoiding ridge saddles, breaks in slope, and relatively low-lying areas. On the other hand, the grading needed for wider roads and larger pads can harm terrestrial biota, and can alter the ways that birds fly over the landscape. Larger turbines are usually mounted on taller towers, so the rotor-swept plane reaches higher into the sky and can kill species of birds and bats that were previously at lower risk. Slower cut-in speeds might increase bat fatalities, and faster cut-out speeds might increase bird fatalities.

Repowering poses special problems to fatality monitoring and to estimating changes in collision rates. Differences in collision rate estimates before and after repowering can be due to climate or population cycles, changes in monitoring methods, and changes in wind turbine efficiency. Fatality monitoring could be more effective when it is (1) long-term, including when the older project was operating at peak efficiency, (2) executed experimentally, such as in a before-after, control-impact design, (3) largely consistent in methodology and otherwise adjusted for inconsistencies, and (4) sufficiently sampling the projects' installed capacity. Another challenge is overcoming public and regulator impatience over documented wildlife fatalities. Fatality monitoring before repowering necessarily reveals project impacts. Repowering can reduce those impacts, but this message needs to be delivered effectively to a public that might be sceptical after seeing the earlier impacts and will want to see trustworthy fatality predictions going forward. Accurately predicting impacts at repowered projects can be challenging because the often-used utilization survey is ill-suited for making impact predictions, and because flight patterns can shift in the face of larger wind turbines and an altered landscape.



# Oral Presentations

The abstracts are sorted alphabetically by the family name of the stated (and underlined) presenter.



## Introducing a new avian sensitivity mapping tool to support sustainable renewable energy development in northeastern Africa and the Middle East

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The risk to soaring bird species posed by poorly-sited wind turbines and power lines is now well established, and poorly located operations can prove both environmentally and financially costly. Consequently, renewable energy companies, planning authorities and others urgently need access to accurate ornithological information to inform site planning. However, at present, relevant data is typically difficult to obtain and interpret. To address this problem, BirdLife International has launched an online mapping tool through which detailed information on the distribution of soaring bird species on one of the world's most important migratory flyways can be accessed. This information can help to inform decisions on the safe siting of new developments, such as wind farms, helping to ensure that negative impacts are minimized.

The Red Sea/Rift Valley Flyway, stretching from the Middle East through north-east Africa, is one of the most important bird migration routes in the world. Hundreds of thousands of large soaring birds, such as eagles, hawks, cranes and storks, pass through the region as they migrate between Africa and Eurasia. The region is currently undergoing a rapid expansion in renewable energy technologies. Given the extraordinary congregations of soaring birds that occur within the region, there is a real risk that the cumulative effects of multiple, poorly-sited facilities along the length of the flyway could be severe.

The Soaring Bird Sensitivity Mapping Tool\*, developed by BirdLife International and habitat INFO as part of the UNDP/GEF funded Migratory Soaring Bird Project, is an innovative tool designed to address this problem. This free, public-access web-resource provides companies and government agencies with spatial and tabular data drawn from established sources on globally threatened species, protected areas and sites of global conservation importance. Records of soaring birds from the scientific literature and from Worldbirds—a global portal for the submission of bird observations—are also incorporated, along with satellite tracking data contributed by researchers. For each location search that a user performs, the tool calculates a sensitivity value based on an analysis of the available soaring bird data. This calculation takes into account the proportion of each species' global population present at the site, the global conservation status of each species at the site and the inherent collision vulnerability of each species based on their morphology and flight behavior. The tool generates tailored reports for each search, as well as providing a wealth of additional best-practice guidance material.

Since its launch in early 2014, the tool has been extremely well received and is expected to become an established source of ornithological information for supporting the environmentally-sound expansion of renewable energy.

\*<http://maps.birdlife.org/MSBtool>

## Activities and fatalities of Natusius's Bat at different wind farms in North-west Germany

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Northwest Germany is characterized as a flat and relatively open, highly agricultural-used landscape. It is also known for strong winds since it situated on the coast of the North Sea. This led to a high density of wind facilities. This landscape also hosts a great proportion of Natusius's Bat (*Pipistrellus nathusii*). Natusius's Bat is one of the most threatened species by collision in Germany. In this talk we would like to compile the results of post construction monitorings from nine wind facilities both on the coast and more inland. The data are part of the evaluation of mitigation measures performed by different consulting agencies. In most cases a carcass search with carcass removal trail and search efficiency control was conducted. Bat carcasses were usually searched every third day. In addition, bat activity was also monitored: In most of the projects, we recorded bat activity at nacelle heights with Anabats SD1 and SD2 (Titley Electronics, Australia) with two exceptions where an Avisoft-System (Avisoft Bioacustics, Germany) was installed. We compare the occurrence of fatalities of Natusius's Bats with the distance to the coast, structure richness, wind turbine measurements, and whether the monitored activity of the species has a correlation to the number of bat fatalities. Because the sites are situated in the different geographical regions, we like to emphasize differences between wind facility sites.

We performed a general linear model analysis (GLM) to identify driving factors of the activity of Natusius's bats (as measured by the contacts) and their fatalities. In our model, the site itself turned out to be a main driving factor, followed by seasonal patterns, and, to a lesser amount, wind speed. Surprisingly, activity and fatalities are not correlated in our region, possibly due to the limited detection range of microphones compared to the blade length. We would like to discuss the implications of our results for further monitoring designs.

## 'Bat-friendly' operation of wind turbines – the current status of knowledge and planning procedures in Germany

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'Bat-friendly' operational algorithms are currently the mitigation measure most commonly used to counteract bat collisions with wind turbines in Germany: During times of high collision risk, rotors are stopped to avoid bat fatalities. The definition for times of high collision risk, however, varies e.g. between different federal states. We give a synopsis of the operational algorithms currently applied in Germany, the most urgent questions related to this method, and some answers from our own studies.

The periods during which turbine rotors should be stopped to reduce the collision risk for bats are usually a function of one or several parameters (e.g. wind speed, month or season, time of night, temperature, and precipitation). The most frequently used operational algorithms are based on standardised data acquisition and analysis, risk assessment, and mitigation cut-in wind speeds that depend on the turbine-specific level of bat activity, month, and time of night.

We tested the effectiveness of the bat-friendly turbine operation in an experiment at 16 wind turbines at 8 sites in Germany in 2012: Fatality rates were successfully reduced to a given limit of 2 animals per turbine per year, as demonstrated by fatality searches. We present data on the usually low cost for implementing and running the algorithms for a data-set of 70 turbines and compare the cost for different years.

The 16 experimental turbines were equipped with at least 2 of 3 different acoustic detector types at the nacelle. Detectors showed substantial differences in downtime and percentage of noise recordings. We discuss consequences for field studies.

The turbines were sampled in 2008 and are being resampled in 2014. For the three year data-set, we will quantify the variability of bat activity and fatality risk within and between years and draw conclusions on one of the most urgent questions regarding operational algorithms: How much data are necessary to assess the collision risk at wind turbines, both on a temporal and on a spatial scale (i.e. how many turbines per site should be sampled)?

Another question concerns the standardisation and simplification of data acquisition and of the development of algorithms. We will present the software tool ProBat that has been developed to allow for an easy calculation of the turbine-specific collision risk and corresponding bat-friendly operational algorithms from data on wind-speed and acoustic bat activity.

## Is there a state-of-the-art regarding noise mitigation systems to reduce pile-driving noise?

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Underwater noise caused by pile-driving during the installation of offshore foundations is potentially harmful to marine life. In Germany, the regulation authority BSH (Federal Maritime and Hydrographic Agency) has set the following limit values: Sound Exposure Level 160 dB and Peak Level 190 dB for marine mammals which must be complied with at a distance of 750 m to the construction site. The experience from previous years shows that produced underwater sound during pile driving depends on many parameters and measurements showing values of up to 180 dB<sub>SEL</sub> and up to 210 dB<sub>Peak</sub>. Therefore, the use of Noise Mitigation Systems (NMS) is requested to significantly minimize hydro sound. Since 2011, NMSs must be applied during all noisy offshore construction work in Germany. The itap measured hydro sound and evaluated noise reduction from the NMS during eleven OWF construction phases (> 700 pile installations without and with different NMS) in accordance with the existing measuring instructions for underwater noise measurements and determination of the insertion loss of NMS after BSH. Additionally, several founded research projects exist in dealing with the identification of influencing factors on noise (e. g. "Big Bubble Curtain" (BBC) *OFF BW II*).

In this presentation, a general overview of existing and tested NMS including tested system variations is given. Thereafter, main influencing system parameters, as well as other potential influencing factors like current or water depth on the effected noise reduction of the BBC based on measured data from research projects and running construction phases, will be presented since the BBC is currently the most used NMS system. Additionally, combinations of two or more NMS are measured during construction phases in Germany if monopiles with diameters of up to 6 m are installed. It will be demonstrated which effects one or more NMS have on the emitted noises. It will be shown that it is possible to install monopiles with a diameter of 6 m with noise levels below 160 dB<sub>SEL</sub> if combinations of suitable NMS are used. Furthermore, an overview of all tested NMS systems in Germany will be presented and the measured data will be discussed. The main results show that noise reduction significantly depends on the NMS system configuration and that with only one NMS noise reduction of 10 dB to 15 dB is possible. The question of if a State-of-the-Art NMS for reducing pile driving noise exists will be discussed based on measured data and experiences with these NMS under real offshore conditions.

## Factors affecting avian mortality levels at onshore wind turbines in the United States

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Wind offers a renewable source of energy that does not produce greenhouse gas emissions. Turbines do, however, cause wildlife mortality through collisions with birds and bats. While differences in turbine specifications, such as hub height, explain some variation in mortality rates, much variation remains among facilities and among turbines within a facility. We analyzed mortality records for ~1200 turbines on monopole towers in the United States to determine whether environmental variables were correlated with the number of mortalities caused by turbines. We fit a hierarchical Bayesian model to fatality counts from mortality monitoring studies. We assumed the number of mortalities observed at each turbine was binomially distributed, with  $n$  corresponding to the actual number of individuals killed and  $p$  describing the observation probability. We modeled  $n$  with a Poisson distribution whose mean was a function of a variety of environmental variables, turbine specifications, and study timing and duration. We used a beta distribution to describe  $p$ , which depended on study design parameters. Environmental variables included land cover within 100 m, 1 km, and 10 km of the turbine, topography, latitude and longitude, mean wind speed and prevailing direction, and the average number of clear days per year. Preliminary analyses indicate the MW capacity of the turbine explained the majority of the variation in mortality rates, with larger turbines causing more mortality than small turbines. Understanding the factors that affect levels of turbine mortality can inform the planning and placement of future wind energy development. It can also be used to project the expected mortality for future development scenarios and explore potential impacts.

## Enhancing the study design of carcass removal trials for bats and birds at wind farms

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Carcass removal trials are mandatory during any wind farm post-construction monitoring. These trials aim to characterize the distribution of time of carcass persistence needed to adjust the number of fatalities observed in wind farms. Typically, these trials consist in placing under the turbines a (frequently small) sample of carcasses which are checked after placement according to a pre-defined inspection protocol. Until now these field methods were mostly defined by empirical results and financial criteria but no information is available regarding how to plan these field methods aiming to minimize estimation errors. Hence, with this study we aim to assess the error associated with the estimation of the mean carcass persistence time as a function of field methods and, based on that, formulate practical recommendations to guide practitioners.

Through simulation we have studied the accuracy and precision of the estimates as a function of sample size, inspection protocol, and the risk of carcass removal. Additionally, we have analyzed data from camera trapping trials to evaluate the influence of continuous vs. censored data on estimation. The mean time of carcass persistence was estimated using parametric survival methods.

The simulation results evidenced the strong negative impact that small sample sizes have on the precision of estimates and justify why small sample sizes, namely under 20, should be avoided. Small length inspection protocols (e.g. 7 days) should also be discarded as they may severely compromise estimation. Protocols with daily visits in the first days after carcass placement, followed by visits longer spaced in time should instead be adopted, allowing diminishing estimation errors whilst procedure costs. Whenever possible, time-extended protocols should be used specially under a small risk of removal. Camera-trapping does not necessarily represent a clear advantage over well-planned traditional trials as similar estimates were obtained from continuous vs. censored data. However camera trapping can still be of great use, especially at remote wind farms, as it significantly reduces the number of visits to check the carcasses.

The results of this study highlight the strong impact that the trials design can have on estimation errors associated with the carcass persistence adjustment and, ultimately, on fatality estimates. We conclude giving practical recommendations and underlying the importance of balancing these guidelines with (1) the particular characteristics of each wind farm, and (2) the focus of the monitoring programme, so carcass swamping and the sacrifice of animals may be minimized.

## Massive bat migration across the Alps: Implications for wind energy development

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For the last two decades, the installation of wind parks in Europe has been accelerated to reach the ambitious targets of the energy turnaround and to combat climate change. Especially hill tops, ridges and alpine passes are benefited from continuous winds. Therefore, remote sites throughout the European Alps are increasingly suggested for wind parks in order to harbour the extensive winds and to concurrently avoid conflicts near human settlements and restricted protected areas in the lowlands. It is well known that myriads of migrating birds regularly cross the Alps in spring and autumn. Many discoveries of marked bats point to the fact that they cross Europe, but the phenology and flight routes of migrating bats are still obscure. In this study, within the framework of an international cooperation throughout the European Alps, we aimed to undertake long-term observations of bats to better understand the seasonal occurrence of local and migrating bat species.

We conducted continuous acoustic monitoring using broadband ultrasound recorders on towers, in the nacelle of wind turbines and on the ground from spring to autumn. A dozen recording sites were distributed across the Alps in Austria, Germany and Switzerland, including control sites in the lowlands.

We found a regular presence of bats at sites up to 2500 m ASL, surprisingly high bat species richness at many alpine sites, including both, local and migratory species. While there was a high variability between the sites, we recorded peaks with massive migration especially during a few weeks in autumn. At some valleys and passes in the Alps hundreds of bat sequences were recorded in single nights, indicating that many thousands of bats were crossing the perimeter of a wind park in the course of the season.

Our results clearly demonstrate that the Alps are regularly used for foraging by local bats and as seasonal routes through Europe by migrating bats. We strongly recommend to carefully monitor planned wind energy sites in the Alps, including those in valleys and on alpine passes, and to implement appropriate mitigation measures to protect the threatened bat species.

## A spatial concept for guiding wind power development in endangered species' habitats: Underpinning the precautionary principle with evidence

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The precautionary principle is an essential guideline applied in wind power planning. However, due to the inherent component of uncertainty it has been widely criticized for being "unscientific", i.e. hindering wind power developments without sufficient evidence. This criticism calls for methods to guide action in the face of uncertainty. We addressed this challenge using the example of species conservation versus wind farm construction, an expanding development with hypothesized - but unexplored - effect on our model species the capercaillie (*Tetrao urogallus*). By systematically combining information drawn from population monitoring and spatial modelling with population ecological thresholds we identified areas of different functionality and importance with regard to metapopulation persistence and connectivity. We integrated this information into a spatial concept defining different four area categories with different implications for wind power development. The first category covers the spatial requirements of a minimum viable population, focusing on core areas with reproduction plus the primary "corridors" connecting these habitats. Categories 2 and 3 represent a "safety zone" where turbine construction is not generally banned, but subjected to a thorough evaluation process, whereas the fourth category encompasses all areas neither currently nor potentially relevant for metapopulation processes in the future. Drawing from this example, we strongly advocate making best use of scientific knowledge when defining precautionary measures, if not available on the threat itself, so on the object at risk.

Bird mortality in two Dutch windfarms: Effects of location, spatial design and interactions with power lines

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Numerous field studies have assessed bird mortality rates in windfarms. However, results from different studies are often hard to compare due to differences in methodology. This makes it very difficult to draw conclusions and to use the results in the planning phase of new windfarms (e.g. how to mitigate impacts). In this study we try to assess how bird mortality rates are affected by 1) the location of the windfarm, 2) the spatial layout of the turbines, 3) the surrounding terrain and 4) the presence of other obstacles such as power lines.

We have monitored 91 turbines in two contrasting windfarms in the Netherlands for five years using the same standardized search methodology, including experimental trials for carcass removal and search efficiency. The sites differ in location (coastal vs. inland), spatial layout, turbine dimensions, land use, bird community and flight intensity of birds. In addition, at one site power lines were constructed halfway the monitoring program. Any fatalities from these power lines were also monitored in a separate monitoring program. This enabled us to investigate any interactions between the wind turbines and the power lines and to compare any differences in mortality rates or species composition.

Our results show a major impact of turbine location on the number of bird fatalities, both within the same windfarm and between windfarms. Mortality rates at the coastal windfarm were 3 to 5 times higher than at the inland windfarm. By far the highest mortality rates were found at turbines close to high-tide roosts and at points where (during spring migration) migrating birds leave the coastline to cross the sea towards Germany or Scandinavia. At these turbines mortality rates could rise up to several hundreds of birds per turbine per year.

The impact of the power lines was clearly visible. Where the search areas of the turbines and the power lines overlapped, the number of fatalities doubled. Contrary to our expectations, we found even more fatalities beneath the power lines outside the turbine search areas than inside. We hypothesize that this effect is due to avoidance behaviour around the turbines, where birds may successfully avoid the turbine but subsequently collide with the less-visible power lines. This aspect deserves more thorough investigation.

As several new windfarms are planned to be realised in the coming years, our results can be used in spatial planning to both assess and mitigate potential impacts.

## Reduced effect of wind farms in the Golden Eagle (*Aquila chrysaetos*) in Spain and Europe

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We reviewed the impact of wind farms on the Golden Eagle (*Aquila chrysaetos*) (GE) in Spain in terms of collisions and habitat loss-disturbance (nest occupancy and breeding success). We surveyed 291 facilities including 6,371 turbines at eight provinces comprising 32-33% of the total power output and wind farms installed in Spain. Out of 12,915 fatalities since 2000, only 15 (0.11%) involved GE, mostly occurring in February-March (60%) and October-December (40%). Collisions were found both at dispersal and nesting areas. At a coarse scale there was no relationship between the GE fatality rates and breeding densities or installed wind farms. Average fatality rates ranged 0.0001-0.004 eagles/turbine/year, quite lower as compared to GE collisions in e.g. the USA. At a finer scale we then compared nest occupancy (yes/no) and breeding success (#chicks) related to the distance and size of the wind farm before and after construction by means of GLZ and GLM models, respectively. Analyses were performed considering varying buffer distances taken from the bibliography or existing monitoring guidelines (<1, 1.5 and 3 km radius around the nest). Neither of the GLZ or GLM models for nest occupancy or breeding success showed any significant differences according to the buffer distances or monitoring period ( $P > 0.05$  in all cases). Slight changes during wind farm installation appeared, however, when considering the time before, during and after the turbine deployment. As a conclusion, wind farms seem to have a limited impact on the GE in Spain. The fact that some of the collided individuals were sub adults coupled with field observations while wind farm monitoring, would suggest that floating birds would be more susceptible of colliding than the breeding pairs. The lower impact of wind farms on the GE in Spain would be reinforced by the current long-term monitoring of most of the wind energy facilities during their entire life span and comprising all the turbines. At the European level there is almost a lack of information with only seven cases reported for Sweden. It is noteworthy the lack of post construction monitoring reports from Scotland, where the species is of great concern during the wind farms pre-construction environmental assessments even developing collision risk modeling (CRM). For the rest of its distribution range, there are no reports available to review (e.g. Italy) or probably not much overlap with wind farms yet (e.g. France and the Balkan Peninsula).

## Avian collision risk and micro-avoidance rates determined at an existing off-shore wind farm

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The risk of collision for birds at offshore wind turbines is among the most relevant conservation concerns related to the use of renewable energy at sea. However, information on avian collisions is mostly derived from onshore sites and/or day-time observations, and current model predictions are driven by theoretical avoidance rate estimates. Here, we present for the first time avoidance rate values for night-migrating birds based on measurements within the rotor-swept zone of an operational wind turbine. In 2010, a purpose-built fixed pencil-beam radar (BirdScan) was installed on the research platform FINO1 near the offshore wind farm *alpha ventus* in the German North Sea. BirdScan automatically detected birds in elevations of up to 3.400 m and enabled the calculation of migration rates for different species groups on the basis of specific wing-beat patterns. Migration rates were measured over 7 successive migration seasons within the wind farm and were compared with values from an adjacent reference area outside the wind farm. In 5 out of 7 seasons, significantly higher migration rates were detected inside the wind farm within the lowest 200 meters. In autumn 2012, significantly higher migration rates were found outside the wind farm; in autumn 2013, no differences were seen. The majority of detected signals were classified as night-migrating songbirds. In addition to BirdScan, an infra-red sensitive camera system (VARS, Visual Automatic Recording System) was deployed on the nacelle of a wind turbine in order to quantify the number of birds passing through the rotor-swept zone. Around 82% of all observed flights through the rotor-swept zone occurred at night. Lower numbers of birds were detected within the rotor-swept zone when the turbine was running, indicating significant micro-avoidance (avoidance of the rotor-swept zone). The ratio of events determined with VARS and migration rates measured with BirdScan at relevant elevations yielded nocturnal micro-avoidance rates that ranged from 95.62% to 98.03%. The micro-avoidance rate decreased to 40.73% when the turbine was standing still. This information is an essential prerequisite for the effective use of collision risk models in environmental impact studies. Our study highlights the importance of measuring avoidance rates at various spatial scales and considering diurnal and nocturnal species activities. Funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

## Lessons learned from the benthic monitoring evaluation in alpha ventus

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Numerous ecosystem goods and services such as marine biodiversity, long-term carbon storage, and natural resources (e.g. for fish, birds, mammals and finally humans), are intimately linked to the benthic system. Maintenance of the benthic system at a healthy ecological status is thus of particular interest. The mandatory monitoring concept of offshore wind farm effects on the marine environment (StUK) prescribes extensive investigations on soft-bottom benthos and fouling assemblages of the wind turbine foundations. StUK and studies beyond StUK in the test field *alpha ventus* (North Sea, German Bight) were carried out to evaluate the German monitoring concept. Our investigations show a massive colonization of turbine foundations by fouling organisms and an aggregation of megafauna around constructions, both resulting in a local increase in biomass and species richness of the benthos, but no direct turbine effects on the soft-bottom benthos at the scale investigated. Temporal variations of sediment conditions and benthic communities were similar inside and outside the wind farm area. During the *alpha ventus* case-study, limits of benthic ecological studies according to StUK became evident and recommendations were elaborated for future improvements. Beyond our field studies, an aggregated database of StUK data from approved wind farms and data from research projects serves as the base for large-scale benthic ecosystem analysis. Current efforts are being made to quantitatively estimate benthic species distributions on a transnational scale, a prerequisite for cross-border spatial planning. Further, we strive to estimate species or group specific “natural corridors of variation” to discriminate anthropogenic effects from natural background variability. Finally, functionally sensible areas and important geographic sites that are of public concern regarding ecosystem services and goods are to be identified. This data will be used to provide evaluation criteria for identifying sensible areas in the context of licensing procedures of offshore wind farms and marine spatial planning. Study outcomes (e.g. in terms of maps) are made public via the internet (GeoSeaPortal) in order to provide stakeholders, e.g. authorities and scientific institutions, with scientific advice.

## Offshore pile-driving and young fish, a destructive marriage?

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Given the increasing amount of anthropogenic impulsive underwater sound introduced into the marine environment, a wide-ranging coverage of impacts on marine life is needed. The strongest and acute impact can be expected in the close vicinity of the sound source while more subtle, long term effects can act on a larger scale. This study tackles the impact of pile-driving on post-larval and juvenile European sea bass. First, a 'worst-case scenario' field experiment on board of a piling vessel was carried out with 68 and 115 days old fish, both weighing less than 2 g. Fish were exposed to strikes with a single strike sound exposure level between 181 and 188dB re 1μPa<sup>2</sup>s. The number of strikes ranged from 1,739 to 3,067, resulting in a cumulative sound exposure level ranging from 215 to 222dB re 1μPa<sup>2</sup>s. Immediate and long-term survival of the exposed groups was high and similar to the control groups. The fish showed a depressed respiration during the sound exposure, indicating an elevated stress level.

To assess effects further away from the sound source, we studied changes in fish behavior and physiology in a laboratory setup featuring a sound system that plays recorded piling sound. In the aquaria, single strike sound levels reached 162 dB re 1 μPa<sup>2</sup>s and 2400 strikes led to a cumulative sound exposure level of 196 dB re 1 μPa<sup>2</sup>s. Under these conditions, we observed that normal behavior was disturbed, with an increase in startle responses and stationary behavior at the beginning of the sound exposure, but was re-established shortly after the cessation of the sound. Feeding and respiration were not affected and accordingly, feeding conversion efficiency, Fulton's condition index, length and weight over 15 days were no different than in the "silent" treatment. The specific growth rate, however, was significantly different between treatments, indicating that food assimilation was decreased due to increased stress levels after exposure.

These results indicate that short-term exposure to impulsive sound creates sound pressure levels at the sound source that are below the lethal sound threshold for fish, but above the stress sound threshold, at least for sea bass smaller than 2 g. Furthermore, the sound levels at a wider range can disturb fish behavior. This disturbance, however, was short-lived and little impact on growth and condition was seen in the conducted experiments.

## Forecasting the impacts of future wind energy development on birds and bats in the United States

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Wind turbines kill birds and bats in the process of generating electricity, and this creates management concerns for some species. A number of scientists have developed methods to estimate national levels of mortality from existing wind facilities in the United States (US). Knowing how levels of mortality may change in the future as more wind turbines are installed can help decision makers understand potential impacts and develop avoidance, minimization, and mitigation measures. We present methods, and examples, to forecast annual mortality rates based on scenarios of future increased market penetration of wind energy in the US. Forecasts of future wind energy development in the US have been generated by federal agencies (e.g., Environmental Protection Agency and the Department of Energy) and private companies (e.g., BP and Exxon). Some of these forecasts produce a single national estimate of new installed generating capacity at specified time steps. A new study by the National Renewable Energy Laboratory includes state-level forecasts under different economic scenarios. We used several methods that range in complexity, but all of them link mortality data collected at wind facilities to forecasts of future installed generating capacity to estimate new mortality rates. The most basic approach is a simple extrapolation from existing estimates of annual mortality per MW of capacity, and the most complex approach involves Monte Carlo like simulations that allocate future wind turbines across space using state-level forecasts of capacity and wind power potential maps, then extrapolating future mortality using a hierarchical Bayesian model of turbine-specific mortality. Results indicate that in some cases, data exist to develop species-specific forecasts, but in most cases, data must be combined across species to generate forecasts. Our forecasts incorporate uncertainty from several sources, including variation in mortality estimates from mortality studies, uncertainties associated with the forecasts of future installed capacity, and uncertainties associated with spatial allocation of wind turbines within states.

## Wind farms and Birds: An updated analysis of the effects of wind farms on birds, and best practice guidance on integrated planning and impact assessment

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This report is an update of 'Windfarms and Birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues' (Langston & Pullan, 2003) that was presented to the Bern Convention Standing Committee at its 23rd meeting, and which informed Recommendation 109 (2004) on minimising adverse effects of wind power generation on wildlife.

In the ten years since the original report, there have been advances in wind energy technology and considerable further work on the science of wind energy/avian interactions. Likewise, with the rapid growth of the wind energy industry in Europe, there has been a corresponding development of the policy environment and best practice for strategic planning and project development for wind energy. This new report attempts to bring these developments together in one place to help further understanding of potential conflicts and how these can be minimised to facilitate further growth of the wind energy industry whilst protecting and enhancing Europe's bird populations.

The report concentrates mainly on reviewing the literature since 2003, literature previous to that date being summarised in the original report. As in 2003, the analysis identifies the following key areas of interaction: displacement, collision mortality, habitat loss or change, barriers intercepting movement, and indirect effects on prey availability.

The report also sets out best practice for the integrated planning and assessment of wind energy development in order to avoid or reduce conflicts with nature conservation interests. Vital elements include:

- Strategic planning of the wind energy industry and the use of best practice protocols for individual project site selection, to avoid or minimise conflicts with nature conservation interests;
- Robust Environmental Impact Assessment, including baseline studies, impact assessment and post construction monitoring; and
- Integrated, inclusive and iterative project development taking full account of potential interactions with nature conservation through the entire project development process.

The report finally contains a series of recommendations which repeat and expand on those in the original report, these include a call for co-ordinated and targeted strategic research, the use of strategic planning including Strategic Environmental Assessment, proper use of Environmental Impact Assessment, a precautionary approach to be adopted by regulators, as well as the development of innovative mitigation measures.

## A bird's-eye view of offshore wind energy and wildlife: Optimizing the sampling design for digital aerial surveys

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Seabirds and marine mammals, which are highly reactive to the environmental changes associated with offshore wind farms, have traditionally been counted by observers on ships and airplanes. Recent developments in digital aerial imagery allow for a less invasive and safer census of marine wildlife, thereby solving major problems with previous survey methods. The switch from analogue to digital methods, however, has led to a significant rise in survey costs, because image acquisition, data processing and archiving require expensive equipment and expert staff which limits the affordable number of surveys per season. Consequently, there is an urgent need to consider trade-offs between image quality (resolution) and quantity (coverage) in order to inform the industry and policy makers about cost efficient survey designs that, at the same time, generates significant, interpretable data. Following a traditional transect design (continuous series of images collected along widely spaced trajectories) increases the chance that a wind farm area is chronically under-sampled. Through concentrating and equally spacing digital sampling effort to predefined areas of interest (wind farm areas, habitat patches, and protected areas) and by taking area-specific expectation values and overall probability densities into account, the quantity of images, survey time and costs could be reduced, while the statistical power and biological meaning of the surveys would increase. To test this notion, we carried out experimental trials based on gapless, vertical imagery (flight altitude 420 m, ground resolution 2 cm) of a species-rich area in the German Baltic Sea (Bay of Wismar), followed by a stepwise, post-flight sub-sampling to determine the minimum coverage required for quantifying aggregations of seabird species relevant to planning, i.e., Common Scoter, Common Eider and Long-tailed Duck. Through comparing the results of this experimental study with long-term, large-scale observational data (supplemented with GIS information), we propose a novel nested-sampling approach to surveying pelagic species in digital aerial surveys. Such an optimised allocation of sampling effort based on the geography of potential habitats and the size and scale of a wind farm area has the potential to increase the explanatory power of resulting data and to lower survey costs. We will also look at statistical aspects in order to identify the minimum number of approximate bird observations in relation to the sampling design. AVI-image is funded by the German Federal Ministry for Economic Affairs and Energy.

## A large-scale, multi-species assessment of avian mortality rates at onshore wind turbines in northern Germany (PROGRESS)

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Knowledge about the levels of added mortality in birds due to collisions with wind turbines is based largely on coincidental information and is consequently heavily biased by observer performance and selective reporting. Through standardizing search efforts and controlling for detection bias and variation in carcass persistence, we carried out a representative, multi-species assessment of avian mortality rates for a total of 55 randomly selected windfarm-seasons in northern Germany, including the states Lower Saxony, Schleswig-Holstein, Mecklenburg-Western Pomerania, Brandenburg, and North Rhine-Westphalia. Wind farm sites were situated in agricultural landscape throughout. The survey covered three successive years (2012-2014). Each windfarm was searched systematically for carcasses along defined line-transects (line-transect distance sampling, software DISTANCE) on a weekly basis for at least 12 consecutive weeks in spring and autumn, respectively. Including 7.000 km of total search effort, we found 285 fatalities (approx. one fatality every 25 km). The composition of retrieved fatalities was clearly dominated by large- to medium-bodied, mostly locally staging bird species; e.g. night-migrating thrush species were not detected. Correction factors for carcass removal and distance-dependent searcher efficiency were determined in site-specific experimental trials. The total number of bird fatalities was estimated using the R package "carcass" (<http://cran.r-project.org/web/packages/carcass>) on the basis of actual carcass retrievals, empirically determined carcass persistence times, and searcher efficiency in relation to varying crop coverage. We present the results as yearly fatality estimates per wind turbine or per megawatt installed capacity, if feasible, separately for species group or species. The resulting mortality rates represent key input values for species-specific matrix models that predict the population consequences of additional mortality for selected species in view of the current and projected wind power use in northern Germany. The project provides objective and well-balanced answers to the relevance of the impact of bird mortality at onshore wind turbines. PROGRESS (Prognosis and Assessment of bird collision risks at wind turbines) is funded by the German Federal Ministry for Economic Affairs and Energy.

## Monitoring bat activity and behavior at wind turbines using thermal imagery and ultrasonic acoustic detectors

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Despite considerable efforts to quantify the impact of wind energy development on bats, a paucity of information exists regarding the ultimate causes of bat fatalities (i.e., why bats interact and collide with turbine blades). A number of hypotheses suggest bats may be attracted to turbines as potential feeding, or roosting sites, yet investigations focusing on bat behaviors near turbines are lacking. Between 29 July and 1 October 2012, we monitored nightly bat activity and behavior at 3 wind turbines at a wind energy facility in northwest Indiana using infrared videography and ultrasonic acoustic detectors. Our objectives were to: 1) examine bat activity and behavior near the rotor-swept zone; 2) assess whether blade rotation influences activity; and 3) understand the environmental conditions under which bat/turbine interactions are most likely to occur. We used Kolmogorov-Smirnov chi-square tests and logistic regression to assess patterns of bat detection in relation to behavior, wind speed, and turbine operation. Preliminary results from 1,304 hours of thermal imagery, showed 993 bat observations, which included behaviors such as hovering, flight loops and dives, repeated close approaches, and chases. Bats were detected more frequently at lower wind speeds and most bats altered course toward turbines during observation. Bats typically approached turbines on the leeward side and the proportion of leeward approaches increased with wind speed when blades were feathered, yet decreased when blades were operational. We also observed higher activity during moonlit periods. Echolocation calls were detected during only 22% ( $n = 218$ ) of the video observations, likely due to lack of overlap in the detection areas of acoustic detectors and video cameras. Acoustic calls did not indicate that bats were pursuing nor capturing insect prey on or near the turbines. Although our scope of inference is limited (i.e., based on a limited field of view from 3 wind turbines), our findings suggest that bats may orient toward turbines by sensing air currents and using vision, and that turbulence caused by fast-moving blades creates conditions that are less attractive to bats passing in close proximity. These data will not only advance our understanding of why certain bat species are vulnerable to wind turbines, but also may assist in refining operational minimization strategies and positioning options for acoustic deterrents to reduce bat fatalities at wind turbines.

## After construction changes in bird migration patterns at an offshore wind farm

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Since 2003, several research projects have been conducted at research platforms FINO1 and FINO3 in the German Bight in order to obtain data for the assessment of possible effects of offshore wind turbines (OWTs).

Information from daytime seawatching at FINO1 showed that most bird species avoided the nearby wind farm, but presumably spent more energy due to the detour flight while their risk of collision was accordingly low. Seabirds lost a part of their feeding habitat. Occasionally birds flew through the wind farm, but no collisions were observed. It is estimated that some species pass the marine area around FINO1 yearly in numbers exceeding 1% of their biogeographic populations.

Nocturnal bird movements were studied by radar, camera systems, and microphones. Radar recordings showed that the number of nocturnal bird movements at FINO1 increased after the construction of the wind park. Simultaneously, after construction, numbers of nights with many thrush calls as a measure for birds close to the buildings generally decreased. Accordingly, a comparison of the sums of birds found dead at FINO1 showed a significant decrease after construction. The wind farm with its 12 illuminated OWT, converter station and FINO1 together obviously attracted more birds than the research platform formerly alone. It appears plausible, that birds gathered not only at the research platform but also in the entire wind farm and consequently dispersed over a larger area which led to a decreased concentration at single constructions. Due to technical reasons (dependence of the detectability on weather conditions, the small size of most migrating birds and the large distance to the camera position) we were unable to directly observe collisions with OWTs.

So far, there is no technique available for reliable species-specific detection of collision under all weather conditions. Knowledge on nocturnal migrants and non- or rarely calling species remains scarce. The phenomenon of photo taxis and its possible influence on the birds' orientation abilities are poorly understood.

Overall, the presented effects lead to a species specific risk of collision that varies in time and space due to local weather conditions. It might be sufficient to take mitigation measures against bird strikes in single wind farms in a few nights for a short time to prevent most of the collisions. This will require excellent knowledge of local migration and weather. Further research should focus on cumulative effects of several wind farms.

## Bats are attracted to wind turbines – determining the distribution of bats by a stereo thermal camera system

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Attraction of bats to wind turbines is frequently discussed to be one of the reasons for high fatality rates. Thus, knowledge on activity distribution is vital to improve methods to reduce fatalities. However, no research has yet been conducted on the influence of existing wind turbines on the behavior of bats. We have seen different approaches to reduce fatalities such as ultrasonic deterrents or ‘bat-friendly’ operational algorithms, most of which share the assumption of an equally distributed bat activity in the rotor swept area.

We quantified bat activity at wind turbines as a function of distance to the nacelle with a stereo thermal camera system. Stereo images were recorded in 2008 and 2012 during ten nights at six turbines at four sites in Germany. The turbines were also equipped with at least one acoustic bat detector installed in the nacelle. We triangulated the position of each recorded bat in absolute coordinates with the nacelle of the wind turbine as origin and the rotor diameter as field of view and correlated the results with the acoustic records. Activity decreased exponentially with increasing distance to the nacelle and converged to a constant level. This level describes the normal distribution of bats in free air space without the influence of wind turbines. Bat activity in close proximity (<10m) could not be determined since the nacelle covers most of the field of view. The distribution of bats was based on a total amount of 4468 triangulated bat positions.

We used the distribution of bats triangulated around the nacelle to calculate a novel scaling factor accounting for varying rotor diameters of wind turbines that can be used for calculating ‘bat-friendly’ operational algorithms. As of yet, scaling was based on the assumption that bat activity is equally distributed. When using a uniform distribution, the scaled activity is largely overestimated which reduces the efficiency of the operational algorithms. The relation between bat activity and distance to the nacelle not only enabled us to improve the scaling for operational algorithms but also suggests that bats are attracted to wind turbines.

## Applying the wireless detection system (WDS)—a real-time monitoring tool for porpoise activity around construction sites

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Noise emissions from offshore pile driving of turbine foundations regularly exceed the sound level at which harbour porpoises suffer temporary threshold shifts (TTS). Therefore, harbour porpoises are to be deterred from the vicinity of the construction site before the start of noise-intense activities, and the efficacy of this procedure is to be documented by CPODs. However, CPOD data can only be viewed after CPOD recovery. To enable immediate initiation of mitigation procedures in case of porpoise presence, a real-time monitoring tool is needed. Therefore, Seiche Ltd. (UK) developed the wireless detection system (WDS), which sends porpoise detection data in real-time from the remote recording device to a receiving station on board a ship. The WDS was tested during the installation of 48 piles of the windfarm NordseeOst in the German North Sea. Some porpoises were detected by the WDS, which lead to the immediate redeployment of the seascarer, which proved to be successful.

Furthermore, the performance of the WDS was tested and compared to that of the CPOD. Simultaneous deployments of the CPOD and WDS at the windfarm NordseeOst revealed that both instruments recorded generally similar data. Most porpoise detections (73-89 %) on one device were also recorded by the other within  $\pm$  6 min. Visual observations of porpoises compared to the acoustic recordings on the WDS and CPOD revealed a maximum detection radius for the WDS of 194 m when single clicks and click trains are considered and of 140 m if only click trains are taken into account. In comparison, the mean maximum detection range for the CPOD (which only detects clicks in trains) was 106 m. Both devices recorded no or only very few detections when porpoises were at distances greater than 200 m. Of 80 tracks when porpoises approached the WDS and CPOD closer than 200 m, 39 tracks (49 %) were recorded by the WDS and 32 tracks (40 %) were recorded by the CPOD. Porpoises had to spend on average 271 sec within a 200 m radius of the WDS and 398 sec within a 200 m radius of the CPOD in order to be acoustically detected with a 50 % probability. Several parameters significantly affected detection probability with most recordings when porpoises were swimming towards the WDS and CPOD, were feeding, and occurring in a group size of two (mostly mother calf pairs).

It was found that the WDS was comparable to the CPOD in terms of porpoise detection probability and detection range. The WDS proved to be a very useful tool for real-time monitoring of harbour porpoises within the danger zone around pile driving. It currently is the only remote real-time monitoring tool for porpoises that has successfully been tested under field conditions.

## Red Kites and windfarms – telemetry data from the core breeding range

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Red Kites (*Milvus milvus*) are the second most often reported victims of collisions with wind turbines in Germany. Germany houses more than half of the world's population of Red Kites and, therefore, has a high international responsibility for the protection of this species. The Federal Ministry of the Environment, Nature Conservation and Nuclear Safety funded a field study to investigate why Red Kites frequently collide with wind turbines and which risk mitigation measures are applicable. The study took place in the core of the Red Kite global breeding range in Sachsen-Anhalt between 2007 and 2010. Ten breeding adult Red Kites were equipped with radio tags (7 birds) or GPS satellite transmitters (3 birds). Each bird was tracked for one or two breeding and non-breeding seasons. Data on flight height and habitat preference were collected by visual observations. The collision risk was modelled in relation to the nest's proximity to wind turbines.

Red Kites spent most of their time close to their nests. Even when nest visits were excluded on average 54% of fixes fell into a radius of 1000 m around nests. The data did not indicate displacement of Red Kites by wind farms. Red Kites frequently visited wind farms for foraging and spent about 47 % of their flight time within the swept heights of rotors of wind turbines present in the study sites. The probability of closely approaching a wind farm significantly decreased with the distance between wind turbines and nests. The collision probability model predicted a sharp decrease of collision risk with increasing distance from the nest.

Foraging Red Kites preferred open sites with low and/or sparse vegetation such as bare fields, field margins, and harvested fields. There was a bottleneck in availability of suitable foraging habitat during the peak breeding period in late May and June when single harvested fields and other features such as dunghills, compost plants, and uncultivated areas around wind turbine pylons were visited by many Red Kites. Partially cut alfalfa fields also attracted Red Kites, but only on the day of harvest.

The results clearly indicate that implementing buffer zones around nest sites reduce collision risk. All attractive features within wind farms (e. g. fields harvested earlier than the majority of fields outside wind farms) potentially increase collision risk. The feasibility and efficiency of directing Red Kites away from wind farms by measures outside the wind farms still remain to be shown.

## Are offshore wind farms the wishing table for fish? – How demersal fish species benefit from Biofouling?

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Anthropogenic activities in marine environments generate effects on different scales. Large scale human interventions into coastal and shelf seas can occur e.g. through the establishment of offshore wind farms that substantially alter local habitats. The underwater structures of wind farms provide large arrays of hard-substrates in environments that typically are characterized by soft-bottom sediments. This implicate that in the area of the central North Sea we will have a massive increase of fouling organisms. We expected that this new biomass of fouling organism will have an impact on the local demersal fish fauna, as it will enhance their normal diet composition and food habits. That these artificial reefs will have an effect on the environment is already shown in many studies, concerning e.g. the change in sediments close to the foundations. However, little attention has been paid so far to the potential changes in the food web and the resulting consequences. For this reason, the ability should exist for assessing possible impacts on the biocenosis, especially since many interactions are non-linear and changes in the environment may lead to significant changes in the seasonality of key species. The purpose of this study is to examine the relationship between the biofouling organism community and the local demersal fishcommunity and to find out possible changes in the food web structure. Scratch samples (taken by scuba diving) and video investigations of the Biofouling and fish samples (taken by beam trawl and set net) from 5 years monitoring at the first German offshore wind farm “alpha ventus”, conducted according to German “Standard for Environmental Impact Assessment” (StUK3; BSH 2007), were examined. Additionally fish stomachs from demersal fishes collected in the vicinity of foundations were investigate. The components of the fishes’ diets varied in number and their frequency of occurrence. The major food items in the stomachs of each species should be examined using an Index of Relative Importance. In a second step we want to link the benthos and the fish data in one dataset to describe a “conceptual” food web structure, to show how the different species adapt to the new food source and the influence to the community and further top predators.

## Evidence of absence or absence of evidence? Inferring fatality when no carcasses observed

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Rapid expansion of wind-generated electrical power has raised concerns about turbine-induced mortality of rare and endangered bird and bat species, for which the loss of even a few individuals may adversely affect populations. Evidence that few animals have been harmed is critical to managing the species, but if fatality monitoring at a site results in only a small proportion of carcasses detected ( $g$ ), then finding zero carcasses of a rare species may give little assurance that the actual number of fatalities is within tolerable limits for its conservation. A Horvitz-Thompson-type estimator typically used to estimate total mortality as  $\hat{M} = X/\hat{g}$  (where  $X$  is the observed count and  $\hat{g}$  is the estimated probability of detecting a carcass that has been killed by a turbine) can only return  $\hat{M} = 0$  with 0 variance if no carcasses are observed, not accounting for the possibility that there were (perhaps many) fatalities but all carcasses were missed during searches. To address this shortcoming, we present a Bayesian-based approach that uses information about the search process and estimated detection probabilities to construct a posterior distribution for  $M$ , i.e.,  $Pr(M|X, \hat{g})$ , reflecting the observed carcass count and estimated  $g$ . From this we calculate two values relevant to conservation: 1) the conditional probability that  $M$  is below a pre-determined limit after observing  $X$ ; 2) the minimum detection probability ( $g$ ) needed in designing monitoring to assure with  $100(1-\alpha)\%$  credibility that  $M$  is below a pre-determined limit, even if  $X = 0$ . This approach allows wildlife managers to distinguish when observing few individuals of an endangered species can be interpreted as evidence of its absence rather than simply absence of evidence.

# Offshore wind farms in the southwestern Baltic Sea: A model study of regional impacts on oxygen conditions and on the distribution and abundance of the jellyfish *Aurelia aurita*

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This study assessed the impact of secondary hard substrate, as being introduced into marine ecosystems by the establishment of offshore wind farm pillars, on the occurrence and distribution of biomass (e.g. mussels, jellyfish) and subsequent impacts on environmental conditions, including potential threats for economic sectors. Offshore wind farm piles are an attractive colonization surface for many species. Especially in marine areas dominated by soft sediments, wind farms may lead to a significant increase in biomass by enlarging habitats from benthos layers into the pelagic column. The present study investigates,

(a) the regional impact of multiple wind farms in the southwestern Baltic Sea on oxygen concentration levels and on the appearance of hypoxia. Increased oxygen depletion is a concomitant effect of the introduction of additional biomass into marine systems. Underlying processes are oxygen consumption through respiration of living biomass and, more importantly, through degradation of dead biomass, mainly *Mytilus edulis*. This leads to impacts on the regional oxygen budget, and local anoxia in the direct vicinity of wind farm piles has been documented in scientific literature. This issue is of great relevance for the Baltic Sea which is already suffering from a lack of oxygen. A five-year data sampling with a steel cylinder and fouling plates delivered data for a 3D ecosystem model. The results show that wind farms do not lead to a significant decrease in oxygen on the mesoscale level. But additional anoxia may occur locally, which may lead to the release of hydrogen sulfide on a microscale level and potential subsequent regional impacts.

(b) impacts of offshore wind farms on the occurrence and distribution of the moon jellyfish *Aurelia aurita* in the southwestern Baltic Sea. A two-year data sampling was conducted with removable settlement plates to assess the distribution and population development of the scyphozoan polyps. The data collected from these samples were used to set up a model utilizing the Lagrangian particle technique. The results confirm that anthropogenic hard substrate (e.g. offshore wind farms) has the potential to increase the abundance of the *A. aurita* population. The distribution of wind farm borne jellyfish along Danish, German, and Polish coasts indicates conflicts with further sectors, mainly energy and tourism.

## Wind farms in areas of high ornithological value - conflicts, solutions, challenges: The case of Thrace, Greece

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Mitigating climate change and conserving biodiversity are both crucial in the efforts to protect the environment. One tool with a fundamental role in the former issue is the development of wind farms. However, as wind farms pose serious threats to birds, their large scale development can create substantial problems to biodiversity conservation. Such a problem is especially acute when wind farms are installed in areas of high ornithological value. If these areas are also valuable for wind farm development then it is critical to find solutions that can resolve these conflicting priorities.

Thrace, in northern Greece, is such an area. It is both an area of great ecological value, due mostly to the endangered bird species found there, and an area of significant value to wind farm development, due to its high wind potential that led to its designation as a priority area for their development. The goal is to establish wind turbines with a total capacity of 960 MW. Today, the area contains 181 wind turbines with a total capacity of roughly 250 MW already in operation.

As Thrace is of vital importance for the survival of vultures and large birds of prey like the Black Vulture (*Aegypius monachus*), the Griffon Vulture (*Gyps fulvus*), the Egyptian Vulture (*Neophron percnopterus*), and the Golden Eagle (*Aquila chrysaetus*) for which wind farms' impacts are considered to be the most critical, finding a solution is paramount for preserving Thrace's biodiversity. Such a solution must address cumulatively the wind farms' impacts, based on sound scientific evidence that consider the ecological links between seemingly distinct ecosystems, and must lead to specific proposals according to the precautionary principle.

In order to produce the best possible solution, we used data generated from our long term research in the area; the spatial use of the Black Vulture population estimated through satellite and radio telemetry studies, the extent and distribution of bird mortality incidents due to collision with wind turbines, and the nesting sites of territorial birds of prey.

The results of the above research studies were combined to produce a map that identifies two zones for protecting biodiversity: The Exclusion Zone, with areas where wind farm installation must be prohibited and the Increased Protection Zone, with areas where wind farm installation could be permitted according to certain conditions. Apart from excluding wind farm development from crucial ornithological areas, this map also identifies areas appropriate for sustainable wind development.

Since producing this map, WWF Greece has lobbied for the inclusion of this crucial data in the licensing process of individual wind farms in the region. In addition, WWF Greece has advocated, in multiple consultations with authorities, in favour of a strategic approach that could lead to a long term solution. It is evident though that without significant changes at policy level there is little chance of resolving the conflict in Thrace between the priorities of wind farm development and biodiversity conservation.

## Bird collisions at OWEZ offshore wind farm measured with WT-Bird

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To date, the number of birds that collide with offshore wind turbines has only been estimated based on collision risk modeling (CRM) and experience with wind turbines on land. No actual measurements of collision rates have been carried out due to the practical difficulties related to monitoring collisions offshore. As a result, actual offshore collision risks are unknown and estimates largely depend on data on avoidance behaviour of birds around wind turbines, which are scarce and highly variable. In recent years, several techniques have been developed to measure actual collisions offshore. Only a few of these, if any, have been tested offshore.

To improve our insight in collision risks offshore and to validate an automated detection method, we are measuring collision rates at one offshore wind turbine for two years. For this purpose, a WT-Bird detection device (developed and owned by ECN) has been installed at the Dutch Offshore Wind farm Egmond aan Zee (OWEZ). This WT-Bird device consists of two acoustic detectors per turbine blade, combined optionally with three cameras covering the entire rotor-swept area. Acoustic impacts are recorded, along with visual footage of the minutes prior to and during the impact, thus providing information on collisions and species involved. We will combine the recorded collisions with measurements of bird flight intensities and avoidance behaviour, in order to be able to assess the results on collisions in the context of local fluxes and avoidance rates.

Here we address the techniques currently available or in development in Europe and the USA and their status, and present the first results of ongoing measurements with WT-Bird. We present preliminary data on the number of collisions, diurnal distribution of collision events, and bird species involved. Bird fluxes at the time of events are presented as well as flight patterns at the site. Results are compared with estimates of bird collision rates as calculated for OWEZ based on CRM and avoidance rates.

With this study, the use of acoustic/visual detection devices to measure collisions of birds with offshore wind turbines can be propelled forward. The results are among the first of its kind and can be used to calibrate collision rate models.

## Using spatial analyses of Bearded Vulture movements in southern Africa to inform wind turbine placement

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Concerns over CO<sub>2</sub> emissions during energy generation and its effect on climate change have led to increased use of renewables, such as wind energy. In southern Africa, bearded vultures have declined by >30% during recent decades. They are now regionally, critically endangered with only around 100 active pairs remaining. This species is considered particularly vulnerable to collision with wind turbines which are planned within their southern African range. In this study, we develop habitat use models using data obtained from bearded vultures of different ages fitted with GPS tags from 2009-2013. We further refined these models by incorporating flying heights at risk of collision to predict important areas of use that may conflict with wind turbines. Adult and non-adult bearded vultures mostly used areas with high elevations and steep, rugged topography in the core area; adults tended to use areas in relatively close proximity to their nest sites, whereas non-adult birds used areas dispersed over the entire species range and were more likely to fly at risk height in areas that were less used by adults. Altitudes of fixes of adults and non-adults showed that they spent 55% and 66% of their time at heights that placed them at risk of collision. Examining the locations of two proposed wind farms in relation to our model of predicted 'at risk' usage suggested poor positioning. Indeed, one of these wind farms was located within the 1% of 'worst' (most heavily used) sites for non-adult bearded vultures, suggesting that its current location should be reconsidered to reduce the impact on this vulnerable species. We demonstrate the value of habitat use models for identifying intensively used areas, where a species may come into conflict with developments such as wind turbines, before these developments occur. This tool is therefore potentially invaluable for planning. Habitat models such as this could easily be used for other species given the availability of similar data.

## Exploring the utility of bird-borne telemetry in wind energy environmental impact assessment

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Rapid technological advances in bird-borne telemetry offer great potential for studies of an ever-increasing range of bird species, to answer specific questions at the level of individual birds. This approach is complementary to larger-scale study methods, such as the use of radar. Focusing on colonially breeding seabirds and proposals for offshore wind energy generation, this technology can yield information about spatial and temporal distributions, connectivity between land-based breeding colonies and different sea areas, including those proposed for wind energy developments. Furthermore, tracking technology can be used to investigate behavioural responses to operational wind energy installations and individual turbines, depending on the data resolution of the tracking instrumentation. The data lend themselves to analytical modelling incorporating environmental covariates. These opportunities require high standards of deployment; bird welfare being paramount, so the choice of device and attachment method are critical. Sample size is an important consideration, to permit scaling up from the individual level. This presentation considers the possibilities and limitations, drawing on practical examples. Satellite telemetry of northern gannets from the only mainland breeding colony in England has provided information about sea areas used during chick-rearing, post-breeding dispersal and early migration periods during three years. The research question was to identify sea areas used, their relative importance and the overlap with proposal areas for offshore wind energy developments. The extent of coincidence of distributions of individual tracked adult gannets with proposal areas varied spatially and temporally. Satellite telemetry was used in this case because of the difficulty of accessing the colony. The potential to continue such work to investigate behavioural responses, by adult gannets, to operational wind turbines has prompted consideration of the available telemetry options, their advantages and limitations.

## Eagle conservation plan and the NEPA environmental assessment: Permitting nexus of adaptive management and mitigation

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The Alta East Wind Project, located in the Tehachapi Wind Resource Area in California, is undergoing NEPA analysis for an Eagle Act take permit under the guidance issued in 2009, and will be among the first projects to acquire a permit for take of golden eagles by a wind developer. We developed an Eagle Conservation Plan (ECP) for the application for the take permit, which included a detailed risk assessment and golden eagle fatality estimate. Although multiple mitigation methods are available for offsetting estimated eagle take, power pole retrofits offered the most precise quantitative method to conduct a resource equivalency analysis (REA) that established the mitigation requirement. With an approved ECP, we developed an applicant-prepared environmental assessment (EA) for the USFWS, who provided review and revision for multiple versions prior to the draft EA. This presentation will focus on 1) alternatives development (variations in the adaptive management plan for each alternative that might be selected), 2) ECP development of REA and compensatory mitigation, and 3) advanced conservation practices (ACPs) and the challenge of quantification in the absence of robust technical knowledge in the context of federal permitting. Alternatives development was sometimes challenging because the effectiveness of experimental methods was unknown, which also involved uncertain costs. Aspects of the ECP take estimate provided opportunities to refine the Bayesian risk assessment, while sometimes highlighting limitations of the model when assessing variability of avian data across the site. Among the most challenging tasks in the EA was determination of the benefit of ACPs, when triggered under various alternatives.

## From gigantic databases to targets of interest: Using machine learning techniques to filter radar databases

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Due to several sampling advantages, marine radar systems that use specialized software to detect and track birds' movements are being widely used to study birds' movements at wind farms. One of the main challenges of such technology is the production of massive databases of moving targets, which beyond targets of interest include non-biological targets that constitute noise to the survey purposes. There are data collection procedures available that remove a significant part of this noise (e.g. reducing radar sensitivity), but this usually implies losing important bird activity.

We tested and compared the performance (accuracy, specificity, and sensitivity) of 6 machine learning (ML) models (random forests (RF), support vector machine, artificial neural networks, linear discriminant analysis, quadratic discriminant analysis, and decision trees) in (1) separating non-biological (e.g. wind turbines) from biological targets (birds), and (2) identifying different groups of bird species.

We used data collected by a Merlin Avian Radar System (X-band 25kW Magnetron; S-band 200W solid-state Doppler) at two different locations (a wind farm located in a mountainous area and another in a flat wetland with high bird abundance), for a continuous period of 20 days. This radar system provides a database with a large amount of information about the characteristics of each target, such as reflectivity, size, shape, and speed. During the radar sampling period, a ground truthing (GT) database for each location was also built.

RF outperformed other ML models, consistently achieving higher performances, for all classification tasks. Particularly, in the wind farm area, this model allowed to separate rain and turbines from biological targets with an accuracy of 0.92, revealing a high potential in separating non-biological from biological targets. In the wetland area, random forests models were able to filter four birds groups: Herons; seagulls; storks; and swallows, with accuracies close to 0.80.

ML methods, and RF in particular, can be used to filter large databases produced by marine radars, identifying and extracting targets of interest from the database. This is particularly useful when characterizing birds' movements in wind farms, as it is possible to separate the 'noise' produced by the turbines from the flying birds. Future research should test if the GT process can be improved in order to achieve models with higher performances especially when separating bird species.

## A nationwide assessment of the impacts of wind turbines on bats

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Much research on wind turbines is undertaken at the local scale. Here, in contrast, we report data from a nationwide survey of a representative sample of wind energy installations across Great Britain. As one of the most suitable places for wind energy production in Europe, the UK has seen rapid expansion in its generating capacity over recent years. It is therefore important to consider the impact for national, as well as local, bat populations. We surveyed 46 sites (22.5% of the national total) with at least 5 operational turbines between 2011 and 2013. At each site, searches for bat carcasses were conducted using trained search dogs at 5-8 turbines (mean 6.3) for a period of approximately one month between July and October. Acoustic activity was monitored at 3 of these turbines, at both ground and nacelle-level, using SM2 bat detectors (Wildlife Acoustics). Observer efficiency and carcass removal rates were estimated in trials using dead bats at each site. Most casualties were *Pipistrellus spp.* and *Nyctalus noctula*, with just single records of *Myotis nattereri* and *Plecotus auritus*. The mean casualty rate was 0.66 bats turbine<sup>-1</sup> month<sup>-1</sup>, which is relatively low compared with estimates from some parts of Europe. However, we identified considerable heterogeneity between sites, with some of the highest casualty rates (2-3 bats turbine<sup>-1</sup> month<sup>-1</sup>) occurring in habitats not conventionally considered to be 'good' for bats and at sites with large numbers of turbines: the potential for significant impact on marginal bat populations is therefore a concern. We discuss the predictors of bat casualties and how the findings could be used to inform strategic planning for wind farms at a landscape scale.

## FaunaGuard implemented in the Dutch North Sea; effectiveness of an acoustic porpoise deterrent device validated

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Marine fauna may be adversely affected by marine construction works as a result of physical interaction with construction equipment and/or exposure to high levels of underwater sound. Physical interaction can cause injury or death, and exposure to high sound levels may cause physiological effects (e.g. auditory masking effects, temporary or permanent hearing threshold shifts) or behavioral effects. To minimize the potential impact of marine construction projects on marine fauna worldwide, Van Oord and SEAMARCO together have developed the FaunaGuard, an Acoustic Deterrent Device to (temporarily) deter various marine fauna species from marine construction sites.

The signals that are implemented in the FaunaGuard have been designed and tested for specific marine fauna species. A variety of signals is already available or under development for modular application on various species of marine fish, mammals and reptiles. The most recent (2014) module of the FaunaGuard, for the harbor porpoise (*Phocoena phocoena*), is presented here.

The FaunaGuard (porpoise module) was proposed as a mitigating measure during the construction phase of the Eneco Luchterduinen Wind Farm (a partnership between Eneco and the Mitsubishi Corporation) in the Dutch North Sea. It should deter harbor porpoises sufficiently far away from piling activities so that no permanent hearing threshold shift (PTS) would occur. For this measure to be acceptable to the regulator, its effectiveness had to be validated. The effective range of the FaunaGuard should be larger than the distance at which piling can cause PTS (based on sound propagation modelling).

To establish an acoustic dose-behavioral response relationship and estimate the mean received behavioral threshold level of harbor porpoises for the signals of the FaunaGuard, a porpoise in a pool was exposed to the signals at seven SPLs. Two behavioral parameters were recorded during control and test sessions: 1) The number of respirations and 2) the animal's distance to the transducer. The number of respirations differed significantly between control and test sessions at mean received levels of  $\geq 104$  dB re 1  $\mu$ Pa. The porpoise's distance to the transducer was significantly greater during test sessions than during control sessions when mean received levels in sessions were  $\geq 86$  dB re 1  $\mu$ Pa.

To calculate the effective range of the FaunaGuard at sea, information on its Source SPL and the established behavioral threshold SPL were combined with sound propagation modelling, for the signals of the FaunaGuard. This calculated effective distance was sufficient to prevent PTS in harbor porpoises due to pile driving sound.

Based on above research, the FaunaGuard (porpoise module) has been accepted by the regulatory agency of the Dutch government to be employed during the construction of the Eneco Luchterduinen Wind Farm in order to keep harbor porpoises at a safe distance from the piling activities.

## Methodology to assess impacts to wildlife from wind energy development

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The U.S. Geological Survey (USGS), in support of the Secretary of Interior's New Energy Frontier Initiative, has developed a methodology to assess the impacts of wind energy development on wildlife. This project's goal is to create a probabilistic, quantitative assessment methodology that can communicate to decision makers and the public the magnitude of these impacts on a national scale. Attempting to determine the impacts to all avian species at wind facilities across the entire nation is fundamentally different than existing methods which are used for assessing impact for fewer species at individual facilities. With these differences in mind, the USGS has met with numerous government, industry, academic and non-governmental organizations groups to build this method.

Publically available mortality information, population estimates, species range maps, turbine location data, biological characteristics and generic population models are used to generate both a ranked list of the relative risk to species as well as a quantitative measure of the magnitude of the effect on species' population dynamics. Three metrics are combined to determine relative risk using factors such as the fraction of annual mortality caused by wind turbines, the portion of the population that is exposed to wind turbines, number of offspring and age at first reproduction, and level of habitat specialization. Generic population models are then employed to infer which species will suffer impacts of a magnitude that would result in a negative rate of population growth. The methodology has been performed on over 400 bird species across the United States. Bats have not yet been incorporated into the method due to lacking fundamental data. Investigations with modelled and surrogate bat data are underway.

This method can be scaled down to areas of investigation smaller than the entire nation, but is not suitable for facility or local level assessment. In addition, this method can be used to recommend species for more intensive demographic modeling, or highlight those species that may not require any additional protections due to low levels of population impact. Increased mortality data availability as well as improved knowledge of species' ranges, life histories, and populations would improve the accuracy of the method.

## Wind power planning in Sweden – the treatment of biodiversity and ecosystem services

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In order to combat climate change, renewable energy is of highest policy concern today, which puts wind power in focus in many countries. Simultaneously, wind power comes with certain impacts on biodiversity and ecosystem services, which needs to be handled in policy and planning concerning wind power development. Such impacts concern e.g. collisions with birds and bats, habitat loss and fragmentation due to the new infrastructure, visual and noise impacts, and other. Many of these impacts have a spatial dimension and prediction models have been developed that could be applied. In Sweden, wind power planning takes place on national and municipal levels, where the municipalities have a planning monopoly concerning their own land use. A majority of the municipalities recently updated their comprehensive plans concerning wind power. The aim of this study was to investigate how the Swedish municipalities treated biodiversity and ecosystem services in these plans. For this purpose, we reviewed international literature, national plans and guidelines as well as 95 of the 212 recent municipal wind power plans in order to compare the planning principles and methods applied. It was found that the applied planning principles varied widely between municipalities as well as on national and international levels. Some municipalities applied restrictions concerning protected areas, areas of national interest for nature, cultural and recreational values as well as areas of high biodiversity value without any kind of protection, while others considered wind power development within these areas, sometimes depending on the purpose of their protection status. Furthermore, the national and municipal view on buffer zones around urban areas and single settlements differed and seem to have evolved over time. Modelling approaches seemed not to have been used but certain rules of thumb were common. In order to find sustainable solutions for wind power development in the future, spatially explicit models for taking biodiversity and ecosystem services into account need to be developed and used. In this way, the rules of thumb expressed in the planning principles could emerge into more detailed and accurate representations of vulnerable ecosystem components, useful in integrated sustainability assessment for wind power policy and planning.

## Avian mortality in wind farms: The State of the Art in Spain

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Even being part of the solution to greenhouse gas effects, and consequently supported by conservationists groups all over the world, wind power plants still represent a risk of bird mortality due to collision with turbines. This fact complicates the development of new installations as well as generates a discussion among conservationists opposed and in favour of this kind of green energy. However, during the last decade mitigating measures have been developed and evaluated to both reduce mortality rates in constructed wind farms and assess risk in future wind farms. Spain has experienced very uneven growth in wind energy due to its geography and wind conditions.

A review of avian mortality from wind farms in Spain was done by summarizing the beginning of wind farm studies, the most affected species and variables affecting bird mortality, as well as mitigating methods. Our first papers about wind farms impact in 2004 suggested additional research before and after the construction of wind farms. After that, before-long term studies and before-after impact studies were done, giving a tool to aid planning and conservation, finding the cause of avian mortality, and focusing the mitigation measures in few dangerous points. We obtained favourable results in our studies after the mitigation measures knowing new methods to evaluate the potential risk in new installations. In our last papers (2012) we suggest wind tunnels to predict flight behaviour and predict areas of higher use by soaring birds, enabling us to identify the most dangerous areas before a wind farm construction. These measures have succeeded in reducing avian mortality in wind farms from Spain and we hope are able to assess management of wind farms and future wind farms construction in order to obtain decrease avian mortality without an appreciable reduction in total energy production.

## Compensation scenarios to deal with wind farm's impacts on birds: The challenges of moving from theory to practice

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Wind farms have negative impacts on wildlife, such as direct bird fatality. Raptors and other soaring birds are among the most affected species. To deal with those impacts mitigation hierarchy should be followed: 1) First avoid impacts; 2) minimise unavoidable impacts; and 3) then residual impacts must be addressed through offset/compensation, to achieve “no net loss” or “net gain”. This last step is a “last resort” and can only proceed if residual impacts are acceptable.

Compensation/offset is a recent topic of research and much of the published work regards the creation of new habitats to replace affected ones. Compensate fatality impact is a more complex subject and should be based in sound scientific principles (measures already successfully tested) to ensure their effectiveness.

Habitat management has been used by Bio3 in several mitigation plans in Portugal, both for wind farms and power lines. The main guidelines include: Design the compensation scheme in the early stages of the project; improve habitat conditions outside the affected area but, if possible, in neighbouring areas; and engage all stakeholders, since conservation cannot be done without local communities' support.

To each project, an offset is designed according to the characteristics of the study area and ecological requirements of the endangered affected species. It mainly aims in the promotion of breeding success and/or enhancement of their foraging habitats. Practical examples are: 1) Protection of the known breeding sites; 2) habitat management to promote prey species for raptors and scavenger birds (e.g. *Aquila Chrysaetos*, *Aquila fasciata*, *Neophron percnopterus*); 3) creation of ponds for *Ciconia nigra* aiming the increase of amphibians and aquatic invertebrates; and 4) promotion of extensive grazing (providing pastures and ponds to cattle) to improve feeding habitat to small raptors such as *Circus Pygargus* or other soaring species such as *Pyrrhocorax pyrrhocorax*. All programmes include monitoring schemes to assess biodiversity gains and losses.

In this presentation we will expose the main results for each type of measure, its effectiveness (e.g. the increase of prey abundance), and how the managed areas start being used by the target species. Despite the encouraging results, we also identify a main challenge related with how to accurately assess losses and gains, showing the need to keep implementing and monitoring this type of project to test their long-term effectiveness and/or possible side-effects.

## Avoidance of an offshore wind farm by a breeding seabird has implications for the offshore renewables industry

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Understanding avoidance behavior is key to understanding collision risk. Quantifying collision risk of seabirds is a central issue in the consent of offshore wind farms in the UK, and yet, remarkably few studies have been conducted. Rather, consent relies on exhaustive debate of a hypothetical viewpoint derived from scant evidence. At Sheringham Shoal, consent conditions required validation of the theoretical collision risk upon the Sandwich terns *Sterna sandvicensis* from a nearby internationally important colony. Our unique 5-year study used visual tracking to detail the flight paths and behavior of terns using the site before, during and after the construction and operation of the 88-turbine wind farm. The technique involves following birds at a distance of 100-200 m with a high-speed inflatable boat, with a GPS boat track representing the track of the bird a few seconds earlier. The approach allowed measurement of active avoidance rate relative to passive avoidance where birds avoid risk by chance without taking any evasive action. Boat-based surveys showed the number of birds around the site increased significantly as a result of the use of navigation buoys installed around the perimeter of the site prior to construction, but that numbers declined after turbines were constructed, even prior to full operation. Tracking confirmed avoidance of constructed and then operational turbines. Prior to operation, 98.8% of tracks heading towards the wind farm entered it, with 65.8% of tracks doing so during operation. Of the 49.4% of birds passing within 50 m of a turbine base and thus falling within potential span of the rotors prior to construction, just 4.7% did so afterwards. The flight height distribution shifted downwards to mean that the proportion of birds at risk height declined by more than half. A model starting with passage rate derived from boat-based data and incorporating a number of steps measured from tracks, orientation of operational turbines relative to the main SW-NE flight axis from the colony and the industry standard collision risk model to estimate the probability of a tern colliding with a rotor, predicted that approximately 1 in every 10,000 passages would result in collision. The resulting estimate of collision rate matched theoretical modeling closely, vindicating the decision to consent Sheringham Shoal in the first place and lending weight to the general discussion of avoidance rate. We strongly recommend further before-during-after studies of avoidance behavior of other sensitive seabird species.

## Mitigation of piling noise during construction of offshore windfarms – special focus OWP DanTysk

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Vattenfall is a key player in offshore wind energy. In the EEZ of the German North Sea, the offshore wind park (OWP) DanTysk is currently under construction by Vattenfall within a Joint Venture with Stadtwerke Munich (SWM). Next to DanTysk, the OWP Sandbank is close to the start of construction. Both OWPs are located in the German Bight 70-90km west of the Island of Sylt at the German-Danish border. In 2013, 80 wind turbine foundations and the offshore substation (OSS) were installed at DanTysk. For Sandbank, the installation of 72 wind turbines and OSS is planned for 2015/2016. According to collateral clause 14 of the BSH OWP permits, noise mitigation measures have to be applied during piling to minimise hydrosound emission. For this purpose, project specific noise mitigation concepts are developed including the noise mitigation system itself, but also deterrence measures as well as measurements of hydrosound levels and the presence of harbour porpoise via C-PODs. At DanTysk, 80 monopile foundations for the wind turbines and the jacket foundation for the OSS were installed from March 2013 until December 2013 using impulse piling. To mitigate the generated piling noise, a Double Big Bubble Curtain (DBBC) was used for monopile installation. For the OSS jacket, an inner bubble curtain within the jacket sleeve was implemented as noise mitigation system. During construction, optimization measures of the noise mitigation concept included a large number of variations and optimizations of the DBBC as well as changes in deterrence measures and adjustment of piling energy. The optimization of the noise mitigation concept led to a successful efficiency of noise mitigation and deterrence. Valuable insights from the different measures to mitigate noise generation and noise levels were gained. This included knowledge in respect to noise mitigation but also to logistical, technical, HSE, and general project management challenges. The evolution and results of the noise mitigation concept during foundation installation at DanTysk will be shown and a general overview of noise mitigation concepts and currently available noise mitigation systems will be given. A special focus will be set to technical and logistical challenges as well as lessons learned and future areas of development.

## Towards an instrument for describing and assessing cumulative effects of offshore wind farms on birds, bats and marine mammals in the southern North Sea

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According to EU nature and environmental legislation (e.g. Marine Strategy Framework Directive and Bird and Habitat Directive), the description and successive assessment of possible cumulative effects on marine wildlife is compulsory for environmental impact assessments of initiatives for installing and operating offshore wind farms. So far, however, the lack of proper methods for describing and assessing cumulative effects has been apparent in the procedures of all present wind farms in the southern North Sea, thus causing a growing concern about how to determine the maximum level of acceptable environmental impact on marine wildlife to which each new wind initiative might contribute. This is a potentially very complicated matter, since cumulative effects may include those of every existing or planned wind farm as well as those of any human activity within the range of potentially influenced species.

First of all, an exhaustive list of species of marine wildlife needs to be drawn up for the southern North Sea, containing all species of birds, bats and marine mammals of which a significant proportion of the relevant (meta) population inhabits the area or passes the area on a regular basis. Of these species, distribution maps (in space and time) are constructed.

Secondly, an inventory (in amount, space and time) is made of all relevant human activities and the pressures they may represent for marine wildlife. These include both existing and projected wind farms apart from the new initiative to be assessed and all other potentially impacting pressures caused by human activities (e.g. fisheries, sand extractions, shipping routes, etc.). The potential impacts of these pressures on each of the species are described, using the DPSIR-method ('drivers', 'pressures', 'status', 'impact' and 'response').

The third step consists of identifying the possible vulnerabilities of the species mapped to each of the pressures identified, preferably based on observed cause-effect relationships. In this step it is shown what the impact is or may be of each of the previously identified pressures on each of the species considered, enabling to determine which pressures should be summed up to describe and quantify cumulative effects of pressures of similar or different drivers. Besides quantifying the impact of (cumulative) effects, it is necessary to determine how much impact can be allowed without the risk of jeopardizing the legally prescribed conservation status of each of the species concerned. Thus, species-specific threshold levels of acceptable total effects are being proposed.

Finally, possibilities for measures that might mitigate the negative consequences of the pressures are being investigated and assessed on both applicability and effectiveness. These measures constitute the 'response' (R in DPSIR-method), necessary to prevent the possibly significant consequences of the assessed activity.

## Wind farm impact assessment: Overview from onshore field studies and application in legislation procedures in the Netherlands

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The Dutch government recently published its National Wind Energy Plan, which includes the installation of at least 6,000 megawatts of onshore wind power in the coming years in order to meet its 2020 targets for renewable energy. The plan details 11 locations for large-scale (>100 MW) wind farms as well as incorporating an agreement with regional authorities to further develop at least another 285 MW in smaller onshore wind farms.

The relatively small size of the Netherlands along with its intensive spatial planning means that most of these planned wind farms are located nearby or even within important nature areas, including Natura 2000 sites, migration hot spots, and key sites for sensitive bird species such as Bewick's swan, spoonbill, purple heron, black-tailed godwit, and tern species. It comes, therefore, as no surprise that the Strategic Environmental Assessment of the National Wind Energy Plan concludes for most of the proposed wind farm locations that significant negative effects on Natura 2000 features cannot be excluded beforehand and detailed Appropriate Assessments (AA) are needed. This requires comprehensive knowledge of the species-specific responses to wind farms and the possible impacts of disturbance and collisions to inform the Environmental Impact Assessments (EIA) and further legislation procedures.

Here, we present an overview of recent (field-based) studies that we have carried out in the Netherlands to establish the impact of existing and planned onshore wind farms on birds and detail the methodologies applied. We show how the predicted number of collision victims by collision rate models relates to the actual number of victims in a number of existing Dutch wind farms. We also show how we determine collision rates and how we use radar to assess flight behavior in and around wind farms in order to predict the impacts of disturbance. We discuss the impact of coastal wind farms on nearby breeding colonies of gulls and terns as well as on migrating passerines and how results of the field studies have been used to predict impacts of repowering these wind farms. Finally, we also show how such results can be successfully implemented in EIAs, Aas, and further legislation procedures, including how we evaluate population level effects in the light of legislation. This overview captures the latest methods for impact assessments of onshore wind farms in the Netherlands.

## Bat activity at nacelle height over forests

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Bats are increasingly affected by the rising number of wind turbines, especially onshore. Currently, forested areas in Germany are regarded as suitable sites to further increase renewable energy production through wind energy. Forests are also very important habitats for most bat species serving as hunting ground and/or roost sites. Knowledge about how bats are affected by constructing wind turbines in forests, however, is basic at most. Besides the obvious destruction of roost sites and hunting habitats, collision with operating wind energy turbines is the most problematic effect.

Bat activity in open landscapes at nacelle height in Germany has been recently studied in two research projects and measures to reduce bat fatalities at wind turbines have been proposed. Data on bat activity over forests at nacelle height has only been collected since forest locations are used for wind energy development and nacelle bat monitoring has become a more common practise. Up to now, data collected at forest sites was not analysed on a larger scale. In the research project, "Construction and operation monitoring of wind energy in forests" funded by the Federal Ministry for Economic Affairs and Energy (BMWi), we gathered and analysed a large set of acoustic monitoring data collected at wind turbine nacelles over forests and open landscapes from all over Germany. We analysed relationships between bat activity and meteorological parameters, described daily and annual phenology of bat activity, and species composition. The results were compared to previous findings for open landscapes in the same geographical regions.

Preliminary results show that bat activity over forests is very similar to open landscapes. Daily and annual phenologies, as well as species composition, are similar in forests and open landscapes, however, depending on geographical region. As in open landscapes, bat activity over forest decreases with increasing wind speed and decreasing temperature. These results suggest that mitigation measures, developed to reduce bat fatalities in open spaces, are also applicable to wind turbines placed in forests.

## Wind turbines and birds in Germany – a review of current knowledge, new insights and remaining gaps

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The impact of wind turbines on birds has been discussed in Germany for almost 25 years now. The current practice in the planning process of wind farms can be characterized as a mixture of more or less scientifically based knowledge and precautionary assumptions. The basic principle of avoiding or at least reducing the impact of wind turbines on certain species of high conservation concern is to maintain a sufficient distance between wind farms and breeding sites or important roosting areas.

Based on the list of species with respective distance recommendations, this talk gives a review about the current knowledge concerning the species specific sensitivity against wind turbines. Exemplary research results illustrate that in some cases the impact is not as severe as assumed, which is even confirmed in some court decisions. On the other hand, the growing concern about cumulative effects or new findings led to an enlargement of recommend buffer zones and incorporation of additional species.

Apart from the review of the available literature, new results of several own research projects are also presented. Examples are the development of populations of certain red listed species in agricultural landscapes close to wind farms over a period of 13 and 6 years respectively, the barrier effect and collision risk of a wind farm close to a roosting site of 20 000 bean geese, and the impact on migrating cranes.

On the basis of the presented research results covering the different impact types (collision, displacement, barrier), the importance of a sound scientific base for planning recommendations and decisions is emphasized. Remaining gaps are highlighted with corresponding recommendations for future research and improvements in the planning process. With regard to the cumulative impact of collision mortality, it is proposed that the protection of vulnerable species on the population level should be addressed in the regional planning system while the protection of individual birds – most important in German jurisdiction – can only be handled on the level of the individual planning case. Distance recommendations are of general help, but should be regarded as adaptable on the basis of reliable data concerning the spatial use of the birds in the specific planning situation.

## Acoustic telemetry for fish – applications for monitoring and management

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In basic monitoring surveys, the impact of offshore wind turbines on the marine environment is mostly assessed using traditional methods. As an example, the BACI (Before-After-Control-Impact) method evaluates possible effects on fish species, linking spatio-temporal changes in densities to changes in the environment. This methodology has important drawbacks as it only reveals changes in large patterns but does not explain the underlying causes and processes. Disentangling the processes behind the observed impacts helps to understand the impacts and plays an important role in management decisions.

*In situ* observations of fish behaviour and movement may provide valuable insights for monitoring purposes. However, directly observing behaviour of fish in the wild is logistically very difficult. An interesting technique to infer fish behaviour is acoustic telemetry. This technique allows us to track individual fish over a long period of time without disturbing them. Using acoustic telemetry to monitor the impacts of offshore wind farms allows us to understand specific fish behaviour and distribution related to these artificial structures as it gives detailed information on presence of the fish over time, day-night movement patterns and exact location of the fishes within the wind farms.

In this oral presentation, results from research on acoustic telemetry performed in the offshore wind farms in the Belgian part of the North Sea will be presented. From 2009 until 2012, the behavioural ecology of Atlantic cod (*Gadus morhua*) was investigated. The study revealed that cod has high site fidelity, shows crepuscular movements related to feeding activity, and is very selective in habitat choices. In addition, some applications and designs that may be useful for future monitoring and management purposes will be discussed.

## The effects of construction and operation of wind farms on harbour seals (*Phoca vitulina*)

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The rapid expansion of the marine renewable energy industry makes it imperative to understand potential effects on marine life. The Wash in South-East England hosts a large population of harbour seals (> 3,500 individuals) and is also an area of extensive wind farm development. In The Wash, we deployed telemetry tags on 24 seals prior to any wind farm development (2003-2005) and on 25 different seals during wind farm construction and operation (2012); these tags provided both locational and behavioural information. We also obtained data on the timing and location of construction activities (pile driving) from the wind farm developer. Using the telemetry data, underwater sound propagation models and various statistical techniques including state-space models and generalised estimating equations, we addressed the following questions: Was there a difference in seal distribution in the vicinity of wind farms (1) prior to development compared to during operation, (2) prior to development compared to during construction and (3) within the construction phase during piling compared to breaks in piling? Finally (4), we examined if the sound levels predicted to be received by the tagged seals exceeded current published thresholds for auditory damage. In comparison to prior to development, there was not a decrease in the relative abundance of animals in the vicinity of either the wind farm under construction or in operation. In fact, one individual appeared to be attracted to the foundations within the operational wind farm. Furthermore, there was no large scale displacement of animals during individual piling events. The closest distance each seal came to pile driving varied between 4.7 and 40.5 km. Analysis of the predicted received sound levels suggests that half of the seals experienced permanent auditory damage. These results greatly enhance our understanding of the environmental risks associated with the marine renewable energy.

## Noise mitigation reduces negative effects of pile driving on harbour porpoises

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Construction of offshore wind farms goes along with considerable noise emissions during pile driving. Several studies demonstrated clear avoidance behaviour of harbour porpoises (*Phocoena phocoena*) in quite extended areas around such construction sites due to underwater noise.

In order to protect marine mammals, especially harbour porpoises, noise mitigation techniques have to be implemented during pile driving in German waters. The aim is to reduce noise to a threshold of 160 dB SEL at a distance of 750 m to the sound source.

The construction process of three German offshore windfarms (Borkum West II, Global Tech 1, and DanTysk) was accompanied by research projects in order to investigate the effectiveness of noise mitigation tools (e.g. the Big Bubble Curtain).

The behaviour of harbour porpoises was investigated by use of up to 26 passive acoustic data loggers (C-PODs) placed at different distances from the construction area. These devices recorded porpoise echolocation clicks and, thus, gave information on the presence of these animals on a high temporal resolution. Data were analysed with respect to whether the spatial and temporal scale of porpoise avoidance behaviour differed with different noise levels.

Results show that the application of noise mitigation techniques like the bubble curtain reduced the spatial scale of porpoise avoidance behaviour of up to 90 %. Reducing impact zones of sound emission during pile driving may be the most successful way to mitigate negative effects of offshore construction on marine mammals. This is particularly relevant with respect to plans of building several wind farms simultaneously in the same area.

## WREN – A new international collaborative under the International Energy Agency

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Concerns over the environmental effects of wind energy continue to challenge the wide scale deployment of both offshore and land-based wind projects. To address this challenge at the international level, the International Energy Agency (IEA) has approved the addition of Task 34 to the portfolio of research activities within IEA's Wind program. Six countries, including Germany, Netherlands, Norway, Sweden, Switzerland and the United States, are the founding members of Task 34, now known as WREN, which is defined as 'working together to resolve environmental effects of wind energy'. WREN is envisioned to become the leading international forum for cultivating deployment of wind energy technology across the globe through a better understanding of environmental issues, efficient monitoring programs, and effective mitigation strategies. During the first phase of this 4-year activity, two primary products will be developed by the collaborative: 1) one or more white papers on topics that focus and facilitate discussion on and advance the state of understanding of global concerns within the wind community; and, 2) a hub, a database platform where all WREN-related information will be located. The first white paper will cover issues related to adaptive management, including the risks and challenges associated with implementation of adaptive management for wind projects and approaches to overcoming those challenges. The online hub platform will facilitate finding information on completed and ongoing research, and will provide tools for communication and collaboration. The hub will be a centralized collection and access to knowledge on land-based and offshore wind energy regulatory structures, environmental effects, impact reduction, monitoring methods, and research being conducted around the world. It will include effective monitoring practices and strategies for impact avoidance, minimization, mitigation, and compensation. Additional functionality will include access to research results, white papers, key contacts, and pertinent events for the wind community, and facilitate information-sharing activities (web meetings/webinars, annual seminars and workshops) for the international wind community. This presentation will describe the status of the development of WREN and its relevant current and pending activities.

## Measurements of hydrosound emissions and soil vibrations during monopile installation with combinations of independent noise mitigation systems

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For the installation of pile foundations for offshore wind turbines (OWT), impact driving is the dominating technique due to technical and certification reasons. This method causes hydrosound emissions which are harmful to marine life. For projects in the German North Sea, limiting values defined by German authorities have to be complied with to protect the marine fauna. These limiting values are to be kept by the use of noise mitigation systems (NMS). However, especially when installing large diameter monopiles, the use of a single NMS is not sufficient to achieve these requirements. Recently, combinations of several NMS were used to improve noise reduction. To reduce noise caused by impact driving more effectively, the damping effects of different NMS in different frequency ranges need to be studied. Research is also necessary on the effects of soil vibrations that are caused by impact driving and induce hydrosound into the seawater in further distances from the pile. To contribute to a better understanding of the wave propagation running from the pile into the seawater directly and via the subsoil, three offshore measuring campaigns were executed at the offshore wind farm (OWF) Amrumbank West. A dense matrix of hydrophones in different heights over ground and a line of geophones were deployed in distances between 15 to 750 m to the monopile during pile driving with different combinations of the two NMS Hydro Sound Damper (HSD) and Big Bubble Curtain (BBC). The comparison of time synchronised hydrosound and seismic data allows the calculation of travel times from which the type and the way of the shock waves can be concluded. Analyses of acquired signals in the time and frequency domain, used to study wave characteristics and damping effects of HSD and BBC as well as influences of the subsoil are shown. This can lead to an optimisation of particular NMS and their operation. Based on the measurements described above, the wave propagation in a wide radius from pile driving is described. However, phenomena occurring under different boundary conditions like stratified soils or sound channels as well as soil vibrations due to alternative installation methods like pile vibration require further research.

## Impact of wind turbines on woodland birds

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The installation of wind turbines in forests is a rather new phenomenon in Germany as well as in most other countries. Consequently, very little is known about the specific impact of wind farms on woodland birds. In a three year study funded by the German Ministry for Economic Affairs and Energy, the displacement effects on woodland birds were studied during 14 wind farm seasons using an impact-gradient design, an impact reference-design, and a before-after design.

So far, fieldwork was carried out in 2013/2014 at 12 wind farm sites in German low mountain ranges covering a total of 66 wind turbines (two wind farms were surveyed in both years). At all sites, a breeding bird census of selected species (mainly red-listed) was conducted in an area of 500 m around the turbines, and 1000 m, respectively, for soaring birds and birds-of-prey. In 2014, a reference site of similar dimensions which was at least 1000 m away from wind turbines was added for seven wind farms. Furthermore, a complete breeding density census was conducted throughout the study at each wind farm in a sample area adjacent to a turbine and in a reference area with similar habitat at a distance of at least 1000 m to the next wind turbine. For eight study sites pre-construction data are available.

In the data analysis, several difficulties of the study design became apparent like the comparability with pre-construction data due to differences in field effort, or the problem to find suitable reference areas due to mosaic-like variation in habitat structure. A discussion of methods on how to study impacts on birds by wind farms in woodlands and recommendations for selected woodland species will be provided.

Preliminary results show that the species composition is quite similar between the wind farm sites and the reference areas. The originally assumed shift from woodland species to open and semi-open landscape species due to forest clearances of up to 5.000 square meters per turbine could not be confirmed. By using the impact-gradient and the before-after design we could identify some species with a reduced breeding density in turbine vicinity. Thus it seems that certain woodland species show sensitivity against wind turbines. One possible explanation might be acoustic disturbance like masking of courtship calls. The results are related to the current knowledge in the literature comparing woodland and open-land species and remaining uncertainties are highlighted.

## Can video images of bird strike contribute to the elucidation of collision mechanisms?

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A current theory advocated for bird collisions with wind turbines is the motion smear theory (Hodos, 2003). Other proposed theories include low visibility in fog or snowstorms and the visual contrast between a wind turbine and the background (MOE, 2013). However, video images that captured the moments of bird collisions with wind turbines are not yet available. These images could elucidate collision mechanisms and contribute to preventing collisions. Entrusted by the Ministry of Environment (MOE), we started the project in 2013 to record the moments of bird collisions.

A wind turbine located at northern Hokkaido, Japan with a high risk of bird strikes was monitored using a webcam surveillance system that was activated during the daytime every day from December 2013 to March 2014, which was the wintering season for the white-tailed sea eagle (*Haliaeetus albicilla*). The surveillance system included two web cameras, namely MOBOTIX DualDOME D15, and a NAS server, namely Buffalo Tera Station TS-XH4.0TL/R6. The imaging interval was ten frames per second.

A collision carcass of the white-tailed sea eagle was observed at the wind turbine on January 29, 2014 at 15:00. On analysis of the recorded data, we found that the moment of the collision was captured by both cameras. A part of the video is published on [http://youtu.be/T1jSEpEV4D0?list=UUI\\_vpnyuAvUewfQG8B962xg](http://youtu.be/T1jSEpEV4D0?list=UUI_vpnyuAvUewfQG8B962xg).

We would like to discuss the following four findings that were observed in the video. First, the collision was not induced by poor visibility; the visibility was good before and after the incident. Second, the occurrence of motion smear is suggested because the eagle collided with the blade tip. Third, the blade was moving downward when it struck the eagle. The postmortem reports from other individuals suggest that the eagle was also struck from behind (MOE, 2014). Finally, the eagle that had collided with the wind turbine seemed to be chased by another bird. This led to a new hypothesis that the interaction between the two individuals could have caused the collision. Our research demonstrates that video images can provide various kinds of information and can even lead to new hypotheses. Further video images should be recorded in order to verify these findings and accordingly, the development of a system for obtaining images of birds that fly around wind turbines is required.

## GPS telemetry reveals within-wind farm behavior of Lesser Black-backed Gulls during the breeding season

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As part of the UK Government's commitment to obtaining 15% energy from renewable sources by 2020, several offshore wind farms have been built, are under construction, or are proposed. Seabirds might be affected by offshore wind farms through displacement from foraging habitat, collision mortality, presenting barriers to movement, or changes to habitat or prey. Many seabirds are feature species of Special Protection Areas (SPAs), yet the behaviour of birds within offshore wind farms for specific SPAs is poorly known. We used GPS telemetry to directly study area usage and behaviour of Lesser Black-backed Gulls within offshore wind farms at two geographically distinct UK SPAs during the breeding season. In total, 25 birds were tagged at Orford Ness, Suffolk (Alde-Ore Estuary SPA) between 2010 and 2011, and 24 at South Walney in Cumbria (Morecambe Bay SPA) in 2014; both SPAs are in foraging range of several existing wind farms. We explored the horizontal space use of birds using kernel density estimation (KDE) methods of GPS locations, and vertical space use using Bayesian modelling of GPS altitude data to explore flight heights.

At Orford Ness, 19 birds showed connectivity with offshore wind farm areas between 2010 and 2012. At South Walney, 13 birds showed connectivity but there was a much greater proportional overlap of both total and core area usage with operational wind farms at South Walney than at Orford Ness. At South Walney tracks of birds often showed striking sinuosity around individual turbines, information that is useful to understand micro avoidance. Flight height analyses indicated the majority of birds flew below the minimum heights of turbine blades at both sites, which has important implications for understanding general collision risk in this species. Some individuals also regularly commuted through existing wind farms to reach foraging areas beyond.

Our results have revealed previously unknown details of behaviour in relation to offshore wind farms for this species, but highlight the need for further long-term, multi-colony investigations to allow the effects of offshore wind farms to be appraised within environmental impact assessments.

## Radar assisted shutdown on demand ensures zero soaring bird mortality at a wind farm located in a migratory flyway

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Wind energy is considered a clean energy source, but produces negative impacts regarding avian mortality. The Barão S. João wind farm (25 turbines, 50MW), located in SW Portugal, is part of a migratory flyway of international importance, being crossed by ca. 5000 individuals of over 30 soaring bird species every autumn. The wind farm's licensing was conditioned to the implementation of rigorous mitigation procedures, namely a Radar Assisted Shutdown on Demand (RASOD) protocol, in order to reduce the probability of bird casualties from collisions.

A security perimeter with observers aided by radar detected soaring birds approaching the wind farm, whose turbines were to be turned-off when pre-defined *criteria* of intense migration or presence of threatened species were met. Turbine shutdown was operated by the wind farm staff (2010-2012) after a request from the monitoring team (MT) or directly by the MT (2013).

The average annual number of soaring bird movements in the wind farm area summed 3400, involving 27,000 individuals (same flocks may overfly the area repeatedly in consecutive days). 72% of movements and 43% of individuals were recorded at flight altitudes associated with collision risk. Based on mapped routes of soaring birds, we estimated that a minimum of 570-1550 individuals were at high risk of colliding with the turbines so far. However, as a result of RASOD, no soaring birds died from collisions during four consecutive autumns. This result is relevant since several highly threatened species and large flocks of griffon vultures, which are known to have high mortality rates related to collisions with wind turbines, migrate through this area.

The use of radar increased the procedure's efficiency, allowing an early detection of birds and improving the prediction of flight trajectories. Nearly 40 % of the shutdown orders were caused by the presence of birds first detected by radar.

Average annual shutdown period decreased continuously after the first year (105 h) reaching only 44 h in 2013, when the MT was given direct access to shut down operations through SCADA. Shutdown period corresponded to less than 0.5-1% of the equivalent hours in a year's wind farm activity. Nearly half of the shutdown periods occurred at wind speeds below 5m/s, resulting in low production losses.

Our results indicate that RASOD may be an essential tool in reconciling wind energy production with the conservation of soaring birds in areas where such a conflict may emerge.

## Does noise mitigation matter? Population consequences of piling noise on marine mammals with and without the application of noise reduction methods

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The growth of the offshore wind industry has led to a wide scale construction of large offshore wind farms in European waters. As part of the construction process many wind turbine foundations are installed with impact pile driving hammers which generate significant underwater noise. These noise levels have the potential to impact marine mammals as a result of auditory injury and behavioural changes, including spatial displacement. Using noise reduction mitigation, for example, bubble curtains or coffer dams, is a way of reducing the amount of acoustic energy propagating through the water column, thereby reducing impacts.

Noise reduction mitigation is often expensive and logistically difficult to achieve, therefore quantifying the potential to reduce impacts to marine mammals, both at an individual and population level, will be important to fully understand the positive benefit of such techniques.

For demonstrating and quantifying the reduction in impact that could potentially be achieved, we used the interim Population Consequences of Disturbance (PCoD) model. The PCoD model uses the same stochastic population dynamic modelling approach as population viability analysis (PVA) coupled with expert opinion on the effects of disturbance on an animal's vital rates where empirical data are lacking. It provides a rigorous, auditable and quantitative methodology, supported by the best available evidence, to assess the consequences of construction noise on a range of marine mammal populations in UK waters. We used this model to explore the population consequences of "real world" wind farm construction scenarios in UK and German waters, allowing a comparison of population level cumulative impacts with and without noise reduction techniques.

## Using miniaturized GPS to monitor the movement of bats in proximity to wind turbines

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An essential aspect of impact assessment of wind turbines on bat populations is the question how local bat populations respond to the presence of wind turbines. We studied the spatial behavior of noctule bats (*Nyctalus noctula*) when commuting and foraging next to wind turbine facilities. On the species level, noctule bats make up the majority of fatalities at wind turbines in Northeastern Germany, and therefore an impact assessment is highly relevant for this species. We monitored the spatial use of bats by equipping bats with units that recorded GPS locations at nighttime at intervals of 30 seconds. Used GPS units exceeded the preferred 5% threshold value of body mass. Nonetheless, our preliminary assessment revealed that the foraging behavior of bats (average body mass 34 g) seems to be unaffected by this additional load. Our study population inhabited artificial bat boxes set up in a forest fragment in northern Brandenburg close to the city of Prenzlau. The forest fragment was surrounded by numerous wind parks. The closest wind park was at 2.3 km distance to the bat roosts. In male noctule bats, we retrieved 6 out of 11 GPS units, when units fell to the forest floor below bat boxes. We were able to record spatial data ranging from 1 to 4 nights from individual bats. Male noctule bats foraged at distances of 1 to 7 km from their daytime roost. Possibly, bats avoided areas covered by wind farm facilities for both commuting and foraging, yet it is unclear whether this is caused by wind turbines or whether bats used traditional flight paths and foraging areas that were established before wind turbines were present. Our preliminary data suggests that GPS tracking of bats may become a powerful tool to assess the potential impact of wind turbines on bat populations. However, the success of this technique depends on retrieving GPS units, which is best achieved when bats are accessible in artificial boxes. Further miniaturization of GPS units will make this technique useful as well in other bat species. However, considering practical and financial constraints intrinsic to this technique, we refrain from recommending this technique for routine consultant work at this stage.

## Predictive modelling versus empirical data – collision numbers in relation to flight activity in 55 German wind farm seasons

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One of the key concerns related to wind turbines is the risk of direct collision of birds with rotor blades. In order to improve the assessment of bird collision risk, we present some of the first results of the German PROGRESS project (funded by the German Federal Ministry for Economic Affairs and Energy), which included an extensive post-construction research program combining carcass searches and vantage point (VP) watches in 55 wind farm seasons at 47 different wind farms in 2012-2014. This enabled us to quantify bird activity and categorize the behavior of different species flying close to the turbines. The aim of the project was – *inter alia* – to be able to compare the determined collision numbers (estimated after incorporation of correction factors) with the expected numbers calculated with the Band Model using the flight data obtained during the VP watches. The VP surveys comprised daylight observations from two fixed locations at each site. Besides other parameters, flight duration of each target bird was recorded on a weekly basis for at least 12 consecutive weeks for a total of 36 observation hours at each VP. As collision risk is thought to be most dependent on bird activity, flight altitude and avoidance behavior, flight heights were classified into height bands (below, in, and above rotor).

As there is still a large degree of uncertainty about the level of avoidance, collision risk estimates derived from the Band Model are highly sensitive to variation in this factor. During PROGRESS, birds were followed individually to quantify avoidance behavior, as birds may either alter their flight paths around whole wind farms or actively avoid the rotating blades within wind farms. The overarching approach of this part of PROGRESS was to use actual flight data and actual mortality to back-calculate this correction factor for a group of target species. First results show the linear relationship assumed between the estimated number of birds at rotor height and the actual recorded bird mortality often does not hold.

On the basis of the comparison of determined and calculated collision numbers, we are able to discuss the uncertainty levels of assumed avoidance rates and bird activities as a result of VP watches. Thus it is important to realize that “avoidance” may in fact encompass different sources of error in the model, which incorporates a range of biological variation. This will lead to an evaluation of the Band Model predicting collision numbers in the light of ecological stochasticity.

## Estimating the effects of breeding season displacement and barrier effects from offshore wind farms on seabird demographic rates

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The potential for offshore wind farms to impact seabird populations by either displacement or barrier effects have been widely acknowledged. It may be expected that impacts will be greatest during the breeding season, as central place foragers seabirds are constrained to obtain food resources within a limited distance from their nest location. Displacement and barrier effects would manifest themselves in changes to time and energy budgets of adults, potentially reducing body mass, nest attendance or chick provisioning rates, ultimately affecting adult survival and breeding success. However, a comprehensive assessment of the population level consequences of displacement and barrier effects for seabirds had not been undertaken.

In recognition of this, the Scottish Government commissioned The Centre for Ecology and Hydrology to quantify the consequences of displacement and barrier effects during the breeding season on demographic rates of four seabird species (guillemot, razorbill, puffin, kittiwake) at four breeding colonies in south east Scotland where four wind farms within the foraging ranges of the birds have been proposed. A simulation model estimated time and energy budgets during the chick-rearing period, with individual birds making foraging decisions assuming optimal foraging theory. Simulations were run for baseline conditions i.e. without wind farms, in the presence of each individual wind farm, and for the cumulative effects of all four wind farms. Effects on breeding success and adult mass were estimated by the model directly, and published equations were used to predict the consequences of changes in adult body mass on survival.

Results indicate species, colony and wind farm specific differences in the magnitude of effects on both adult survival and breeding success. They also indicated differences in the relative importance of displacement and barrier effects in the estimated changes to demographic rates. The estimated cumulative effects logically comprised of approximately the sum of the individual wind farm effects.

This oral presentation will describe the project methods and results, and discuss how the research outputs have been used to inform assessments of offshore wind farms in Scotland. Furthermore, it will discuss how this approach can be improved in the future, by addressing key areas of uncertainty through additional research.

## Evaluating the effects of offshore wind farms on fish: Experiences from the Netherlands

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In 2006, the first Dutch offshore wind farm was built 10-18 km from the shore of Egmond aan Zee by a joint venture of Nuon and Shell Windenergy. A Monitoring and Evaluation Program accompanied the plans for the construction and exploitation of this farm. Potential ecological consequences for fish were hypothesized to be linked to the introduction of new habitat, i.e. the monopiles and the scour protection surrounding them, disturbance by the operation of the wind farm (e.g. noise), and the exclusion of fisheries in the wind farm and its surrounding safety zone. To monitor and evaluate these hypothesized effects, evaluation studies were performed focusing on different parts of the fish community, their spatial and temporal distribution, and their behavioural aspects. To study the demersal and pelagic part of the fish community, BACI-approaches were used, before (T0), and after the construction (T1, T5) in both the offshore wind farm and two reference areas using trawling surveys and acoustic surveys. On a smaller scale, species composition and abundance of fish in the vicinity of the monopiles in the wind farm were studied using gillnets and DIDSON (acoustic high frequency camera using sonar) in three seasons during the T5. Behaviour of individual fish in and around the wind farm was studied by a tagging and telemetry study for which sole (*Solea solea*) and cod (*Gadus morhua*) were selected to represent both sand and hard substrate dwelling species. The surveys monitoring the species on a larger scale in the Dutch coastal zone did not show significant effects of the wind farm on the abundance of fish in the farm compared to the reference areas. On the smaller scale of the wind farm, clear differences were observed between the new artificial hard-substrate habitat and the sandy bottom. Large aggregations of fish were observed near the monopiles mainly in summer. Furthermore, a significant higher abundance of cod, bib (*Trisopterus luscus*), bullrout (*Myoxocephalus scorpius*), sea scorpion (*Taurulus bubalis*), and common dragonet (*Callionymus lyra*) was observed on the scour protection near the monopiles. Lower abundance was observed for the flatfish species, sole, dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*) and also for whiting (*Merlangius merlangus*). For some species, higher abundance near the monopiles may lead to protection from fisheries and a potential positive effect on their populations. Overall, the presence of the wind farm seems to have limited effects on the fish community of the Dutch coastal zone. For some species local benefits due to a combination of the creation of new hard substrate habitats and exclusion of fisheries might have occurred. Finally, the different study designs used to evaluate ecological effects on fish will be discussed.

## Bird migration monitoring in the Saint Nikola Wind Farm territory, NE Bulgaria, and analysis of potential impact after five years of operation

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In NE Bulgaria, AES Geo Energy OOD constructed a 156 MW wind farm, the St Nikola Wind Farm (SNWF), consisting of 52 turbines. In autumn 2008, SNWF did not exist; in autumn 2009 the facility was built but not operational, and in the autumns of 2010, 2011, 2012 and 2013, SNWF was operational. SNWF is located approximately three to seven kilometers inland from the Black Sea coast and the cape Kaliakra. The SNWF area consists mainly of arable land involving small-scale cultivation of different crops, heavily intercepted with tracks and wooded shelter belts. Important Bird Areas (IBA) in Bulgaria are selected using an in-country standard for the site's importance. IBA "Kaliakra" is designated as it is the only site in Bulgaria that keeps the remaining Eastern Dobrudzha steppe, as well as the biggest sea cliffs along the Bulgarian Black Sea Coast. The IBA is also designated as an important site for migrating birds along the Black sea coast (Via Pontica migration flyway). It is considered to be a bottle-neck migration site with annual aggregations of more than 29,000 storks, pelicans, and cranes, and more than 3,000 birds of prey. This study presents the comparative results of six autumn seasons at the SNWF, with a focus on the impacts on migrating birds. Data gathered from visual observations are analyzed. The data from the autumn monitoring in the years 2008 to 2013 are used to investigate the potential change in species composition, numbers, altitude or flight direction of birds observed in these 6 years at SNWF. The variations in numbers of species, absolute number of birds, overall altitudes of flight, and migratory direction of birds most sensitive to wind turbines do not indicate an adverse effect of the wind farm on diurnal migrating birds. The Turbine Shutdown System probably contributed to a reduced risk of collision during all years of operation within infrequent periods of intensive soaring bird migration and provided a safety mechanism to reduce collision risk for single birds and flocks of endangered bird species. The low number of victims of collision found during systematic searches for casualties under every turbine at an interval of 7 days or less in four autumn seasons does not provide evidence for additional mortality caused by SNWF that could be problematic to populations of any bird species migrating through the territory. The results to date indicate that SNWF does not constitute a significant obstacle or threat, either physically or demographically to any of the populations of diurnal autumn migrants observed in this study. The main results of the autumn monitoring of bird migration in the vicinity of SNWF in previous years are published at:

<http://www.aesgeoenergy.com/site/Studies.html>. The results of our study may contribute for the future understanding of cumulative impact of wind parks and habituation process in different bird species including thus with high conservation value.

# Short Presentations

The abstracts are sorted alphabetically by the family name of the stated (and underlined) presenter.



## The importance of offshore bat investigation in wind farm plannings

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Historic observations along with more recent coastal and offshore bat monitoring activities in Europe and North America have demonstrated that bats frequently occur offshore on remote islands, weather buoys, ships, and other structures during migrational periods, and occasionally at great distances from the mainland. Moreover, many of these offshore migrational patterns reflect those observed in terrestrial settings, particularly in terms of the regional and seasonal movements of individual species. Given the apparent concerns over bat mortality on land, it stands that surveys to assess mortality are similarly needed at offshore facilities. Clearly, such an effort presents a unique challenge to researchers, developers, and regulators alike. A more concise understanding of the regional and seasonal movements of individual species, as well as the weather conditions under which they are most likely to occur, are key components to addressing potential risk. This presentation will provide an overview about bat movements offshore, and include the range of methods to survey offshore activity of bats. First, experience at offshore wind farms will be presented and discussed taking into account the question of collision risk. We raise the question whether post-construction bat monitoring methods from on-shore can be transferred to offshore studies.

## Ecological equivalency and offsetting in the context of offshore wind farms: Myth or reality? A discussion on the practice of offsetting through the example of offshore wind farms projects in France

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France is currently leading a policy of marine renewable energies, and especially offshore wind farms (OWFs) projects, in order to meet the ambitious EU climate and energy legislation package and to create an industrial sector. Several site locations of OWFs have been defined by a consultation process and awarded to competing developer consortiums through a national call for tenders in 2012 and 2013. In France, like any European country, an OWF requires an environmental impact assessment in accordance with French and European environmental regulation. This regulation framework involves the implementation of the mitigation hierarchy, i.e. envisaging measures that would avoid, reduce and, if possible, offset significant adverse effects on ecosystems and human activities caused by OWFs projects. The mitigation hierarchy purpose is the achievement of no net ecological losses in order to conciliate human activities development and biodiversity conservation, by ensuring an ecological equivalency between ecological losses caused by a development project, and ecological gains provide by offsets.

The aim of this communication is to question the practice of the mitigation hierarchy, and especially offsetting, and its relevance with the ecological equivalency assumption, in the context of French OWFs projects. We will look in particular how credible is the ambition to achieve an ecological equivalence with offsets.

Our analysis suggests that different pitfalls are likely to alter the implementation of no net ecological losses objective, and therefore to jeopardize its success from an ecological perspective. Among them, failures in the scientific field seem to be the most important. Scientific knowledge in regard to the functioning of marine ecosystems is still limited and complicates the environmental impact assessment. Moreover, it appears that only few compensatory actions are available in regard to the marine environment, which leads to constrain the design of offsetting strategy. Supplementary issues must also be taken into account, such as regulatory requirements (or lack of) and social acceptance.

These difficulties tend to lead to a release of initial assumption of ecological equivalency with offsetting actually proposed and offsets could often integrate social expectations. Thus, the design of offsetting might end up giving significant place to human aspects and too little to biological aspects.

## Cumulative effects assessment and the precautionary principle: What goes up must come down. The Scottish regulatory experience with offshore wind and declining seabird populations

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Scotland supports almost half of the breeding seabirds found in the European Union. About 80% of these populations are decreasing. The Scottish Government also has ambitious targets for offshore wind energy generation, as a contribution to the target of 100% of demand being met by renewable energy by 2020. The statutory protection afforded by the Birds Directive means that assessment of the cumulative effects of these major infrastructure projects has been undertaken.

This talk describes how methods to estimate collision and displacement effects are combined for multiple offshore wind farm proposals in order to gain insight into potential population consequences using PVA techniques. The assessment framework relied upon combining multiple modeling approaches for both the estimation of effect and the determining whether estimated impacts were acceptable. The sensitivity of these approaches to precautionary assumptions were a key consideration. An iterative process was used to refine both the size of the wind farm proposals in order to mitigate effects, and the assumptions used to estimate effects.

Four key themes for future cumulative effects assessments are synoptically appraised:

- Regulatory use of a quantitative modeling framework. Providing examples of both mitigation of project proposals, and identification of future research and monitoring which focus on the main uncertainties.
- How much cumulative effect is too much? The benefits to the regulatory process and concepts associated with establishing heuristic thresholds of acceptable change using PVA.
- Issues associated with extending the scope of cumulative assessments to larger spatio-temporal scales (i.e. trans-boundary and across seasons), and to include other human activities.
- Edging closer to the truth whilst retaining precaution: future application of the precautionary principle as we move towards a more realistic understanding of the uncertainties associated with potential effects and likelihood of population changes.

## Cumulative impacts of offshore wind farms on seabird populations: When will compensation for impacts on SPA features be required?

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Large scale Offshore Wind Farms (OWFs) are new to marine environments, the first being constructed in the early 2000s. Europe, and especially the UK, has by far the largest numbers of offshore wind turbines constructed, consented for imminent construction, or being proposed. Their impacts on bird populations are not yet well understood, but collision mortality and displacement/barrier effects can be predicted to cause declines in some seabird populations based on available evidence and current modelling approaches. The North Sea has particularly large numbers of OWFs at various stages of planning; numbers of OWFs will undoubtedly increase considerably in coming years. However, further development could be constrained at some point by impacts on seabird populations. Seabirds thus represent a significant and increasing consenting risk for OWF developers. The Birds Directive requires that projects do not affect the integrity of the Natura2000 network. There are over 80 sites in the Natura2000 network for breeding seabirds in the UK alone, as well as sites for non-breeding seabirds. Cumulative impacts of OWFs are assessed in a precautionary way and at some stage the impacts may exceed sustainable levels. This could limit OWF development, or may require compensation actions to permit development to continue. In this paper we review tools used to assess cumulative impacts on seabird populations, and consider when and where compensation measures are likely to be required. We review Environmental Impact Assessments by OWF developers in order to predict when, where, and for which seabird species, cumulative impacts will exceed levels compatible with the Birds Directive. We outline some possibilities for compensation and discuss how effective these might be, and the extent to which they could satisfy requirements of the Birds Directive. Seabird SPAs differ from most terrestrial protected sites in that compensation cannot be provided by habitat creation to replace lost habitat. Paradoxically, most compensation measures that could be successful in allowing seabird populations to increase would most readily be carried out away from SPA sites. SPA sites tend not to have human impacts that can be alleviated by compensation measures, whereas many small colonies can benefit greatly from measures such as eradication of alien mammal predators. We highlight several compensation measures that would benefit seabirds, including closure of industrial fisheries that deplete seabird food-fish stocks, eradication of invasive alien predators from islands, and creation of new nesting habitat in areas where that limits seabird breeding.

## The Scottish Windfarm Bird Steering Group: A model for best practice and collaborative research?

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The Scottish Windfarm Bird Steering Group (SWBSG) is a unique partnership, formed to examine the relationship between bird populations and terrestrial windfarms in Scotland. The Group provides an independent, objective assessment of the impacts of wind farms on birds.

The Group is a collaboration between government, conservation organizations and industry; acting as a platform for dialogue, ensuring the best use of data and enhancing co-operation. The main steering group is aided by a research sub-group comprising of industry representatives from renewables companies who contribute both data and expertise to the work of the group, as well as helping to ensure that the correct priorities are addressed. Developing a common understanding of the interactions between wind farms and birds is key to both the future development of the industry and to the interests of conservation organizations alike. This can best be facilitated by the Group developing a shared source of data and information, drawn from monitoring and research undertaken both by industry and conservation bodies.

The SWBSG has developed a prioritized program of research to clarify the relationship between wind farms and populations of birds across Scotland. The program covers a variety of industry-identified issues including clarifying the level of any displacement or mortality of birds due to the development of wind farms, and addressing cumulative impacts as the industry becomes an established part of the Scottish landscape and as the number of turbines increases. Projects assessing the efficacy of current survey methodology as well as a categorization of habitat management measures have already been completed, and the second tranche of research is well under way. The research will also help clarify the effects, potentially both positive and negative, of habitat management within the land holdings owned and managed by wind farm development companies. The information gained by addressing these issues will be used to inform best practice guidance for the industry in Scotland and should enable:

- Better sharing and dissemination of data across the sectors.
- Enhanced availability of data to inform disturbance distances and avoidance rates.
- Quicker and more accurate consenting decisions and reduced investment risk.
- The provision of more robust data to inform Environmental Impact Assessments for wind farms in increasingly sensitive locations.
- The reduced need for survey work on the assessment on future sites based on an improved understanding of the interactions between wind farms and birds.

## Beyond monitoring – understanding impacts

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Typically, consent for offshore wind farms comes with requirements to monitor effects on specific environmental receptors, such as changes induced in the abundance and distribution of birds and marine mammals. The stated aim is to test predictions in Environmental Impact Assessments and contribute to an improved knowledge base and hence reduce uncertainties for impact assessments for future projects.

For large scale offshore wind farms, monitoring has been the standard for more than 10 years, being conducted at a large number of sites with very extensive programs across Denmark, Sweden, Germany, the Netherlands, and Belgium.

As a result of this tremendous effort, we now have a reasonably good understanding of the general character and scale of effects at the site level. While there are still effects needing to be better understood, monitoring will only get us so far. Monitoring, no matter how long or well, will never get us any closer to understanding population level consequences of any effects (the impacts) - what environmental impact assessments are ultimately meant to address.

The question is whether we might have reached a point where it would be prudent to shift the focus from basic monitoring of local effects to a more research type effort directed at improving the understanding of population level impacts? Maybe, to the benefit of all stakeholders, resources could be spent more effectively to reduce uncertainties in wind farm planning and impact assessments?

There are huge resources involved in traditional monitoring programmes for individual offshore wind farms, which might do a lot of good being diverted into more targeted strategic research type efforts. It will require some pragmatism and new ways of thinking with all parties, however. Site by site monitoring is the easy choice; the simplest thing to (continue) to do. The alternative may be complicated to handle in the context of consenting individual wind farms.

As developers, we very much have an interest in improving the understanding of population level contexts and consequences of wind farm effects. What is more, we can have a key role to play in making this happen. As some will be painfully aware, poor understanding of population level consequences of wind farm effects leads to very high levels of precaution being adopted in environmental impact assessments, which, in the context of cumulative impacts assessments, is taken to extremes.

Developers can make a difference in this respect, which will be illustrated with an example of an international developer led research project aimed at building an evidence-based modelling framework to better understand the consequences of wind farm developments on the harbour porpoise population in the North Sea.

## Development of wind energy and environmental impacts in Brazil

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Because of increasing climate change considerations and costs related to thermal generation, petroleum prices rise. In addition to major environmental impacts from hydropower, alternative generation technologies have become increasingly important to provide energy sources to warrant increasing development in Brazil over the next decades. Wind energy is becoming an important source to reduce greenhouse gases in the energy sector. The use of wind power has greatly expanded in Latin America driven by the numerous benefits wind can provide, and particularly in Brazil with the support from governmental policies. According to the Brazilian Energy Agency, wind energy capacity will grow from 7 GW at the end of 2015 to 17.5 GW in 2022, implying that a number of new wind power stations will be constructed and operated, particularly in the Northeast. Electricity generation from wind energy has proved increasingly promising, either by the possibility of using renewable natural resources, or as by reducing the magnitude of environmental impacts associated with other traditional energy sources. Adverse biodiversity-related impacts from wind power facilities mainly involve birds, bats, and their natural habitats, either directly through collisions with the rotor blades or indirectly through displacement from otherwise suitable habitat. Furthermore, wind power development has implications for visual impacts, noise, radar and telecommunications infrastructure, access roads, land acquisition, and benefits-sharing, all of which should be considered in the process. In this context, an Environmental Impact Assessment (EIA) report for a wind project is very useful because it specifies each of the actions to be taken during project construction and operation to mitigate any adverse impacts and enhance any positive ones. Although many EIA studies have been done in Brazil, they superficially cover the physical, biological, and social impacts of wind power. Therefore, it is necessary to develop new tools to help environmental control agencies warrant power in wind energy to be better exploited with less negative impact, therefore maximizing its benefits. Given the expected growth, environmental impacts arising from the implementation and operation of wind farms should be considered. The correct location of wind farms can reduce negative environmental effects on biodiversity. After the construction phase, there is a natural tendency of vegetation recovery, which favors the return of the wildlife habitat.



# Poster Presentations

The poster abstracts are sorted alphabetically by the family name of the stated (and underlined) presenter.



## Operational mitigation reduces bat fatalities at the Sheffield wind facility, Vermont

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With growing societal concerns regarding conventional energy sources like oil and natural gas, wind energy has become the dominate alternative energy source in North America and continued development is projected in both the U.S. and Canada. Wind turbines at energy facilities have contributed to bat fatalities across North America. In certain locations, such as the forested northeast, fatalities have been high. As a result, conservationists remain concerned about cumulative population-level impacts of bat fatalities at wind facilities should trends in fatality continue without mitigation. Studies have assessed operational mitigation (curtailment), which raises the cut-in speed of turbines, at reducing bat fatalities only in relation to wind speed. Bat activity varies with environmental conditions like temperature, wind speed, and time of day. Our objectives were to incorporate both temperature and wind speed into an operational mitigation design in order to fine-tune it to weather conditions when bats are most active to improve its effectiveness at reducing bat fatalities. We initiated a two year study from spring 2012 through fall 2013 at the Sheffield Wind Facility located in Sheffield, Vermont, U.S. From 3 June through 30 September of each year, eight of the 16 turbines were randomly selected each night of the study for an equal number of nights at each turbine to cut-in at 6.0 m/s rather than the normal cut-in speed of 4.0 m/s. Treatments were implemented from half an hour before sunset to sunrise when wind speeds were less than 6.0 m/s and temperatures were greater than 9.5° C. Fatalities were estimated using the U.S. Geological Survey's Fatality Estimator software. Bat mortalities at fully operational turbines (i.e., non-curtailed) were 2.7 times higher (95% CI: 1.9, 3.9) than mortalities at curtailed turbines in 2012, resulting in an estimated 60% (95% CI: 29, 79) decrease in bat fatalities. In 2013, we found 1.5 times (95% CI: 0.38, 5.94) as many fatalities at fully operational turbines compared to curtailed turbines. Few bats were found killed in 2013 and small sample sizes that year limited statistical power. Analyses still underway will identify combinations of weather parameters (temperature and wind speed) where operational mitigation was most effective at reducing bat fatalities. We recommend that operational mitigation be implemented during high risk periods to mitigate cumulative impacts to bat populations.

## Alpha ventus: Identifying environmental impacts at the earliest possible stage

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When the first applications for offshore wind farms were submitted to the Federal Maritime and Hydrographic Agency (BSH), many questions concerning possible impacts were far from being answered satisfactorily. Although some experience had been gained in other European countries, concrete data was difficult to apply to German projects which were located up to 150 km offshore and at water depths of up to 50 m. Development of the *alpha ventus* offshore test site was then initiated in 2005 as the nucleus for Germany's offshore wind energy sector.

Ecological research is brought together in the StUKplus project, funded by the Federal Ministry for Economic Affairs and Energy and coordinated by BSH (May 2008 - March 2014). The purpose was to predict the extent to which wind farms will endanger the maritime environment and to identify environmental impacts at the earliest possible stage. The main research topics aimed to provide answers to the following questions: How do habitats change for benthic organisms and fish close to the foundations? How do birds react to the rotating, illuminated wind turbines? Is there a risk of migratory birds colliding with the turbines? What impacts will noise-intensive construction work have on marine mammals and how do they react to operating noise?

The StUKplus project followed a coordinated, synergetic approach: The mandatory ecological monitoring by wind farm operators according to BSH Standard for EIA (StUK) was supplemented with additional research projects conducted over a larger area and at higher intensity, covering benthic organisms, fish, birds, marine mammals and underwater noise. During the extensive field research programme, novel observation methods and technologies such as aerial digital survey techniques and new bird migration radars were applied for the first time in German waters. Being designed as effect monitoring, a before/after comparison study was carried out. Comprehensive preliminary studies were conducted at the test site before construction as early as 2008. To obtain reliable data about how fauna would react to the wind farm in their habitats, long-term studies were performed extending several years into the operating phase.

StUKplus is the most important German research project on potential environmental impacts related to offshore wind farms so far. The final reports are now available for the public ([www.stukplus.com](http://www.stukplus.com)).

## Management of coniferous forests for bats affected by wind farms: Challenges and opportunities for mitigation strategies

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In Europe, bat fatalities caused by wind turbines reach high values at mountain ridges, namely the ones dominated by pine production forests. As it is known, forestry practices play a role on bat richness and activity. Our goal is to identify management actions for coniferous forests that could be incorporated in mitigation strategies defined to deal with the negative impacts of wind farms on bat populations.

To identify the best management practices, bat richness and activity were evaluated in a mountain area in the center of Portugal, during gestation, lactation, and mating/swarming/dispersion seasons in differently managed pine stands. Bat activity was surveyed using acoustic monitoring in 28 sampling points within pine stands with distinct management histories, concomitantly with the sampling of arthropods using light traps. A set of variables were measured in each sampling point to understand if and how vegetation structural components influence bat richness and activity. Through hierarchical partitioning analysis followed by generalized linear models, the variables that best predicted bat richness and activity were identified.

Bat richness and activity were higher in autumn, when mating, swarming, and dispersion from nurseries to hibernacula occur. This peak in activity coincides with the period of higher fatality rate in European wind farms. Prey availability also varied, being higher during the lactation season. Bat richness positively correlated with canopy cover and prey richness, and negatively associated with dry branches cover. Total bat activity was positively correlated with tree height and prey richness, and also negatively associated with dry branches cover. The activity of edge-space foragers was positively associated with average tree height and prey richness, while the activity of open-space foragers was negatively associated with dry branches cover. We identify a set of actions that could be put together in a mitigation context but that first still need to be tested in order to fully understand if those could effectively be used in coniferous stands to mitigate wind farms negative impacts.

## Unraveling the causes of bird mortality with wind turbines: What do we know so far?

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A deep understanding of the factors that explain bird collision risk with wind turbines is crucial to assess the impacts of wind farms: To outline monitoring programs and to implement valid mitigation measures. However, data on the factors influencing collision risk and bird fatality are sparse and lack integration within the literature. In this study we aimed to compile and update the information available on the causes of bird collisions. To do so, we reviewed over 214 peer-reviewed and non-peer-reviewed articles, technical reports, and conference proceedings on topics related to bird fatalities at wind farms.

We could not identify one particular factor as being the main cause of bird collisions. Instead we identified and summarized a wide range of factors influencing bird collisions, which were grouped in three main categories: Species-specific, site-specific, and wind farm-specific factors. Although we addressed each one individually for simplicity, most risk factors show strong connections between them, which we were able to map in a diagram and puts in evidence the complexity of this topic.

The species-specific features influencing collision risk are morphology, sensorial perception, phenology, behavior, or abundance which makes some species more vulnerable to collision than others. Site-specific features include landscape, flight paths, food availability, and weather which explain high fatality rates at specific locations; while wind farm-specific features, as turbine type, configuration, and lighting may be responsible for increasing that same risk.

From the extensive literature review conducted, it is possible to conclude that the understanding about bird collision with wind turbines is infinitely more than in the early years of the wind energy industry. Despite this, we anticipate that the expansion of wind farms to novel areas (with different landscape features and bird communities) and/or innovative turbine technologies may raise new questions and challenges for the scientific community.

## Using bird fatality explanatory variables and conservation status to identify primary target species

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The occurrence of bird collisions with wind farm structures is determined by a complex set of variables that can be mainly grouped according to species features and wind farm site characteristics. Further, the wide variation of inherent species features determines that species are not all equally likely to die from collision and, consequently, the frequency of fatality events varies greatly between species. Therefore, the effectiveness of the research and monitoring programs regarding bird collision at wind farms may be enhanced if centered on objective questions preferably focusing on target species rather than the whole bird community. The objective of this study was to identify the target species that should be primarily monitored in wind farms programs. To identify these species, we have modelled the susceptibility to die from collision as a function of inherent features of the species. Based on the significant fatality explanatory variables, we have constructed a relative fatality index that represents the relative susceptibility to die from collision. To do so we used data collected from 25 wind farms monitoring programs in Portugal that encompass information of about 130 bird species. Variables used to explain the frequency of fatality events variation included relative abundance, body metrics (weight, length, wing span, wing area, wing loading, aspect ratio), and behavior characteristics (type of flights, phenology and gregarious behaviour). Because for several species at several sites zero fatality events were recorded more often than expected (based on Poisson or negative binomial distributions), we used zero inflated mixture models. The observed and estimated values were compared and model selection was performed using information criteria. Based on the significant variables, we have constructed an ordinal relative susceptibility index. The species were ranked according to the constructed index and this information crossed with the species conservation status. Species with higher levels of susceptibility and critical (or near critical) conservation status were identified as primary target species. We conclude identifying primary target species at wind farms and discussing the results considering the implications of (not) using discriminated effort information per wind farm.

## Push and pull: Can habitat management resolve a conflict between wind energy and Montagu's Harrier; a concept based on radio telemetry and observational studies (Northern Germany)

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The Montagu's Harrier (*Circus pygargus*) is rather patchily distributed in Central Europe. Since the 19th century it has suffered dramatic declines, mainly due to loss of natural breeding sites (raised bogs, fens, and reed habitats). The present breeding population in Germany contains some 500 pairs, the federal state of Schleswig-Holstein, one of the most important breeding regions, presently holds 50 to 60 breeding pairs.

Montagu's Harriers have changed their preferred nesting habitat to agricultural crops (barley etc.); consequently, Montagu's Harrier's territories in Schleswig-Holstein are sometimes concentrated in areas with high densities of wind turbines.

To answer questions about habitat utilization and flight activity, the project included telemetry studies and behavioural observations in a project area of some 6,200 ha. Results yielded flight activity data in different flight heights and in relation to the nesting place, home range, and land use. Mapping these results in the project area with some 130 wind turbines, a habitat management concept had been drafted, with areas to attract the harriers to breeding sites outside the high-collision risk sites (close to wind turbines) and to foraging sites also away from the wind turbine concentrations. This made it necessary to not only include one but a high number of wind farms within the project area, and to search cooperation with the local farmers. Wind farm providers have negotiated with the farmers to create and manage breeding and foraging habitats. The concept acts as a framework for the regional spatial planning with respect to wind energy development and includes ongoing monitoring of measures and Montagu's Harrier presence and breeding success. The implementation of the concept is warranted by scientific supervision and participation of the state and county nature conservation administration.

We present the results of this project funded by several sources, give details on the negotiations and alliances to reach a multi-stakeholder accepted habitat management concept, and report about the success so far.

This project has been funded by the German Federal Ministry for Economic Affairs and Energy and local wind farm providers.

## Monitoring the effectiveness of underwater noise mitigation measures during offshore pile driving

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The Federal Maritime and Hydrographic Agency of Germany (BSH) is responsible for the licensing of offshore wind farms (OWF) and for the monitoring of construction and operational phases in the German EEZ. In licenses given by BSH, reference values were introduced in 2003 and turned into threshold values for pile driving noise emissions in 2008. All wind farm and grid operators in the German EEZ are now required to apply noise mitigation systems to keep the following threshold values: Sound Exposure Level (SEL) at 160 dB re 1 µPa2s, and Sound Pressure Level at 190 dB re 1 µPa at 750 m distance from the pile.

Even though a state-of-the-art underwater noise mitigation system was lacking in the beginning, all projects since 2011 have applied noise mitigation systems, e.g. bubble curtains, IHC-NMS, Hydro Sound Dampers, and measures to prevent injuries or other physical damage to marine animals by reducing noise emissions. Meanwhile, noise mitigation systems are well-developed and adapted to project-specific needs. To determine the effectiveness of the noise control systems but also for monitoring possible effects on the marine environment, wind farm operators are conducting dedicated investigations including underwater sound measurements and acoustical recording of the activities of harbour porpoises (*Phocoena phocoena*) in particular, but also visual ship and aircraft-based transect surveys.

The results of monitoring and underwater noise investigations are steadily being delivered to BSH, and they are very promising. It can be shown that the effectiveness of the various noise control systems applied has been continuously improved, which seems to be in turn reflected by the results of the investigations on possible effects of pile driving on harbour porpoises.

By establishing a national underwater noise database for the EEZ that will include results from offshore wind farm pile driving, BSH hopes to be able to provide an overview of past and upcoming underwater noise events in the near future. This will provide a unique overview of noise mitigation measures and their effectiveness, leading to adapted decisions in the approval process of future OWFs and other projects with regard to the protection of marine mammals.

## Phenology of migrating bats crossing Central Europe

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The German Federal Agency for Nature Conservation (Bundesamt für Naturschutz) has funded a Research & Development (R&D) Project on migratory pathways of long-distance migrating bat species. While the entire R&D project consists of four parts, here we focus on the first. For the four species *Nyctalus noctula* (Noctule Bat), *Nyctalus leisleri* (Lesser Noctule Bat), *Pipistrellus nathusii* (Nathusius' Bat), and *Vespertilio murinus* (Parti-coloured Bat) we gathered several thousand observational records from large areas of Germany (Baden-Württemberg, Bavaria, Thuringia, Saxony, Saxony-Anhalt, Mecklenburg-West Pomerania, Brandenburg, and Berlin) and various parts of Switzerland and Austria. Data were taken from published literature and made available to us through databases from Coordination Centres for Bat Conservation, natural his-

tory museums, banding centres, governmental agencies for nature conservation / the environment of federal states, the Swiss Foundation for the Protection of Bats, and individual bat researchers. They include observations from several hundred bat workers across the three countries and span up to three, and even in parts five or six decades.

We analysed the occurrence of the four migratory species over time and space and plotted the phenological presence in the above mentioned sector of Central Europe, which can be considered a “corridor”, as a function of time. This “corridor”, covering more than 1,000 km between the summer roosts in the Northeast and the hibernacula in the South of the project area, reflects the main known migration route.

Furthermore, we combined the occurrence data with land use data (CORINE land cover; ArcGIS10 analyses) in order to find potential correlations to the landscape / land use. We were especially interested in questions such as whether there are areas of higher concentration of animals at certain times and whether there is a link to particular landscape structures or geographical / topographical features (e.g., river valleys, mountain ridges).

The entire project comprised three other methodological parts: (1) radiotracking of noctule bats, (2) evaluation of light-sensitive geolocators on migratory bats, (3) sampling of habitat-specific data on seasonal bat activity.

## Windfarms in Turkey along the migration routes of European migratory soaring birds: Call for an immediate revision of impact assessment

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Turkey lies within the routes of migratory soaring birds, such as storks, raptors, and pelicans. Bosphorus (Istanbul), Kapıdağ Peninsula (Balıkesir), and Hatay Province are main migration bottleneck areas. Turkey has a growing capacity for wind energy. Total installed capacity reached 2.6 GW with 68 wind farms with over 1,000 turbines as of July 2013. By 2023, the build-up power is expected to reach 20 GW, meaning a total capacity of over 500 wind farms or 10,000 turbines. As of mid-2013, 40% of those turbines are located in Marmara region and 16% in the Mediterranean, greatly overlapping the migration bottleneck areas and posing a potential threat to European migratory soaring bird populations.

Data was collected from 15 wind farms across Turkey on the number of birds flying through. Using standard methodology, I estimated the number of migrant birds flying through, the density of bird flow, and the collision risk at those wind farms. Using the mortality rates from my field research and recent migration census data, I estimated the cumulative mortality rate by current and future amount of wind farms at the bottleneck areas, particularly for the White Stork (*Ciconia ciconia*) and Great White Pelican (*Pelecanus onocrotalus*). Analysis suggests that the mortality rate caused by wind farm collisions can be reduced by more than 50% by not licensing 5% of the potential wind farm development areas. Hence, impact assessment of the wind farms along the East Mediterranean flyways of migratory soaring birds requires immediate revision.

## Assessing impacts of offshore wind farms on two highly pelagic seabird species

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Given the rapidly increasing number of offshore wind farms in the German sector of the North Sea, the potential of disturbance of seabirds during the construction phase has to be considered in environmental impact assessment studies. Due to differential sensitivity to disturbances, the effects need to be assessed on a species-specific level. Here, we report the results of monitoring seabird abundance at the offshore wind farm “BARD Offshore 1”. The dataset comprises transect survey data (both aerial and ship-based) of two years pre-construction (03/2008-02/2010), the entire construction phase (04/2010-03/2013), and the first year of operation (since 04/2013). “BARD Offshore 1” is located c. 80 km north of Borkum and holds a typical offshore bird community. Therefore, we place special emphasis on two pelagic species that have not been considered to be highly vulnerable to offshore wind farms so far: The Common Guillemot (*Uria aalge*) and the Northern Fulmar (*Fulmarus glacialis*). Both species show a distinct seasonal distribution pattern with highest densities during summer, which coincides with synchronized post-breeding dispersal of juvenile Guillemots. Our results show that the spatial distribution of Guillemots during pre-construction was similar at the wind farm site and the reference area, whereas the highest densities were observed in the reference area during construction and thereafter. Also Northern Fulmars occurred in significantly higher densities in the reference area since the installation of the first turbines in 2010. Results from aerial survey data covering a much larger area (2,600 km<sup>2</sup>) point in the same direction for both species. This indicates local avoidance behaviour of both species resulting in small scale displacement from the (construction) site of the offshore wind farm “BARD Offshore 1”. Given a distinct seasonal distribution pattern, Guillemots may be especially vulnerable during the post-breeding period when adults guide their offspring to the foraging grounds. Avoidance could be caused by effects of construction activity itself (incl. ship/helicopter traffic) but may also interfere with effects of operating turbines, especially during the third year of construction when most wind turbines were installed. As both species are pelagic, they may perceive wind farms as “land-like” structures and thus avoid the wind farm area. This should be further focused on during the operation phase. Studies from operating offshore wind farms in Denmark and the Netherlands show equivocal results suggesting that avoidance effects both during construction and operation are not only species-specific but also site-dependent.

## Discriminating birds from noise in bird radar data from an offshore wind farm

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Wind farms have several effects on birds. Collision of birds with turbines is one and causes a direct impact as it results in additional mortality for the affected bird species. Collisions of birds with fixed and rotating structures of wind turbines have been recorded in several wind farms on land (e.g. Barclay et al., 2007; Everaert & Stienen, 2007). For obvious reasons, it is more difficult to assess the number of collision victims from an offshore wind farm. Collision models offer a tool to estimate that number. Band (2012) developed a collision risk model (CRM) to assess the bird collision risk for offshore wind farms. The CRM outcome is based on specifications of wind turbines, bird size and flight, avoidance rate and bird passage rates (flux).

Vertical bird radar can provide continuous data on flight movements over a wide range and altitude, allowing users to assess passage rates and altitudes of birds. Not only birds are recorded by the radar; this also happens for rain, waves, boats, wind turbines, etc. These unwanted echoes are being referred to as 'clutter'. To be able to reliably assess the flux of birds in the area it is essential to effectively remove clutter from the radar database.

The objectives of this study are: (1) To develop an analytical procedure to process the data to effectively remove clutter (i.e. data mining); and (2) to continuously determine the flux of birds in the wind farm area at different altitudes and subsequently calculate the collision risk in real time.

The Merlin bird radar system (DeTect Inc., Florida, USA), which is being used, is installed on an offshore platform in a wind farm in the Belgian Part of the North Sea and has been collecting data since October 2013.

To begin discriminating between target types, there is a need for reliable reference data of all objects which are being recorded by the radar. A new software application called Merlin editor is used to manually select different types of targets (e.g. turbines, rain, side lobes, and birds) and to store them in separate databases. These reference data will be used to identify discriminating variables between birds and other objects. Those variables will be identified using different data mining techniques and will allow researchers to create filtering rules to separate clutter from the database. Afterwards, an algorithm based on the same filtering rules will automatically filter new data before being stored in the database.

The filtered data allow proper assessment of fluxes and flying altitudes of birds in the wind farm area. The collision risk will be calculated in real time based on the flux at rotor height. The data processing is ongoing and should allow the reliable determination of the bird flux at various altitudes from fall 2014 onwards.

## Using sealscarers to deter harbour porpoises before offshore wind farm construction: An outdated approach?

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Permission for offshore wind farm construction issued in German waters comes with the attached condition to deter harbour porpoises from the construction site beforehand using three pingers and one sealscarer.

We conducted two investigations on the effects of the Lofitech sealscarer on harbour porpoises and showed that during a near shore visual study porpoises avoided the sealscarer at noise levels above 118 dB re 1  $\mu\text{Pa}^2\text{s}$ , which in these shallow waters was reached at about 2.6 km. A study in deeper offshore waters using acoustic monitoring of porpoises revealed less porpoise echolocation activity at noise levels above 113 dB re 1  $\mu\text{Pa}^2\text{s}$ , which was reached at 7.5 km distance. However, complete deterrence was only achieved with noise levels at and above 122 dB re 1  $\mu\text{Pa}^2\text{s}$ . Differences between these two studies are mainly due to different sound transmissions in the area, and may also be caused by a greater variation in sound levels at great distances in deeper water and with the different monitoring techniques applied. At the time we argued that sealscarers provide an appropriate tool to deter harbour porpoises from offshore construction sites because danger zones, where animals may suffer from temporary threshold shifts (TTS) of their hearing system, reached up to about 2.5 km.

Since then, noise mitigation techniques have come a long way and during installation of offshore wind farms in German waters in 2014, danger zones for harbour porpoises usually did not exceed a radius of 750 m from the construction site. Under these conditions, deterrence radii of a sealscarer may reach far beyond the needed deterrence distance and may cause unnecessary disturbance that affects an even larger area than pile driving itself. Therefore, sealscarers no longer seem to be an appropriate mitigation tool during wind farm construction, while the application of three pingers with deterrence radii of about 200 m is not sufficient.

Therefore, regulations should be reconsidered and a more appropriate deterrence tool should be developed for harbour porpoises, which does not reach as far as a sealscarer but will show a reliable effect in the area needed. This could be achieved by developing a tool which transmits signals at higher frequencies where porpoise hearing is best and which provides the option of adjusting the sound level.

## Wind farms and a compensatory programme for the Iberian Wolf in Portugal: Seven years of analysis

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Building infrastructures on Iberian wolf territory can originate impacts (disturbance, habitat reduction, and fragmentation) that should be minimised. If impacts are not expected to be annulled by mitigation measures, then compensatory measures should be considered to complement them. These measures are independent from the project. They are applied regarding the integrity and the long-term conservation of the wolf population and are intended to offset the negative impacts. Over the past decade, Portugal has established an ambitious renewable energy programme. Wind energy significantly contributed to that programme with more than 4500 MW of installed capacity. Most of the wind farms in the northern and central regions of the country were developed in remote mountain areas, which have important biodiversity values, such as the Iberian wolf. The Environmental Impact Assessment (EIA) of several wind farms determined some mitigation and compensatory measures for wolf conservation. The compensatory measures are directed to the conservation of wolf habitat and should be applied throughout the whole operational phase of the wind farms.

Since 2007, several projects have been implemented in an integrated way. These projects focused on different aspects of wolf habitat conservation: Forest management (224 ha of managed forests and maintenance of an autochthonous tree nursery), reduction of human/wolf conflict (incentives to traditional herding, K-9 unit for detection of illegal poisons and distribution of shepherd dogs), re-introduction of wild prey (roe deer reintroduction scheme: breeding and quarantine facilities, genetic studies, reintroduction and monitoring plans), implementation of restricted hunting areas (1758 ha created), and public awareness (sessions about the Iberian wolf).

The maintenance, adaptation, and complementarity of the projects are essential tools for achieving the goals of the compensatory programme. At this point, it is difficult to assess direct results on the Iberian wolf conservation, since the majority of projects are medium/long term and their effects will only be cumulative.

## Monitoring seabirds and marine mammals with high definition aerial surveying and image analysis – first results of digital versus visual surveys

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Increasing human activities with offshore wind farm constructions require solid data on seabird and marine mammal distribution and abundance in order to balance economic activities with conservation demands. Recording of seabirds is challenging due to their wide distribution and sensitivity to disturbance. In particular, divers and seaducks flee at great distances to approaching ships and low-flying aircrafts. Therefore, visual aerial surveys conducted at low altitudes are expected to bias the recorded bird distribution and numbers, especially for species that are particularly sensitive to disturbance

The company HiDef Aerial Surveying Ltd. developed a method which uses a high definition video technique for aerial surveys. The system is operated at a survey altitude of 1800 ft (500 m) with 2 cm resolution, which allows the identification of seabirds and marine mammals to the species level. Operating at that altitude prevents disturbance of birds and mammals by the aircraft and thus provides unbiased distribution data. Also, the digital survey method is advantageous over visual aerial surveys with respect to enabling validation of the survey data, accurate flock counts without the need for distance correction, and flight safety.

Digital aerial surveys conducted in the German North Sea and Baltic Sea confirms that the method is highly appropriate for monitoring seabirds. Surveying marine mammals by digital imaging is often discussed as being a challenge due to the fact that animals spend most of the time under the sea surface. High sighting rates of both surfacing and submerged porpoises were found and the technique also proves to be highly useful for surveys of small cetaceans.

For comparing the results of both survey methods, we conducted three simultaneous flights using digital and visual aerial survey methods in the North Sea. First results indicate an underestimation of some bird species by using the conventional low-flying visual aerial survey method, particularly for sensitive species such as the Common Scoter (*Melanitta nigra*).

## High resolution aerial stills photography to monitor seabird numbers and distributions

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The offshore renewable energy industry has grown rapidly over the last decade and advances in digital and optical technology have been exploited for use in offshore surveys of seabirds and marine mammals, particularly in relation to wind energy. Historically, seabird as well as marine mammal surveys have relied upon observer-based visual transects methods. As technology has evolved, drawbacks from visual methods have been overcome by new digital methods and are now used extensively in the UK, the USA, and, since 2014, in Germany. APEM uses very high resolution aerial imagery to provide distribution and abundance data for seabirds and marine mammals. Digital aerial techniques are well-suited to covering large survey areas in a relatively short space of time, and can make good use of short weather windows in challenging environments. Digital surveys are flown at about 1000 feet (300 m) which causes no disturbance to the marine animals, and most importantly are safe for the pilots as the plane is high above the wind farms and other offshore developments. Innovative survey designs, e.g. a grid of image nodes rather than traditional transects, can be implemented. The accurate and precise estimates of bird abundance obtained by digital still surveys make it possible to determine the effects of marine renewable energy developments, the exact geo-referenced locations of birds help inform decisions on spatial planning, and the ability to derive flight heights of seabirds reported on the digital images allowing for collision risk modeling in a later analysis step. This new technology is now commonly used to survey seabirds and other animals in challenging environments and provides the answers needed for Environmental Impact Assessments.

## Vantage Points vs. Satellite monitoring of wind farms in South Africa: An example with the Verreaux's Eagle (*Aquila verreauxii*)

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Preconstruction guidelines for birds at South African (SA) wind farms have been recently reviewed. Vantage Points (VP) have been widely suggested as a visual technique to assess both the flying time and rates over project areas. However, enough effort (time/VP) is required for a proper assessment. Scottish Natural Heritage (SNH) suggests 36h/VP while the SA guidelines suggest 48h/VP in a year. We compare results from VP monitoring vs. satellite tracking of Verreaux's Eagles (*Aquila verreauxii*) at three project facilities in the Karoo, Northern Cape Province. Two VE (a male and a female) were fitted with GPS/ARGOS solar PTT transmitters since early 2014. We only used those GPS locations where the eagles were flying, assuming it was not visible for observers at VPs while perched. VP monitoring only sampled 0.69-0.97% of the time (daylight hours) as compared with the whole time covered by the PTT's. VPs only recorded 1.27-3.81% of eagle movements as compared with the satellite. Nevertheless, the most useful information refers to the representativeness of the sample from VP's. The number of eagle contacts per VP significantly differed from those downloaded from the satellite at the three wind farms (Chi square test,  $p<0.001$ ). This may have management implications regarding mitigation or avoidance measures, leading to wrong decisions. Wind farms in SA are usually located in very remote areas and also comprised of a high number of turbines. This makes it difficult to design appropriate field monitoring, requiring a lot of time and effort. In addition, knowledge of SA bird's behaviour towards wind farms is lacking. For VP monitoring, we suggest to increase the sampling hours per VP in order to reduce such bias. This is a key point in vast areas like the Karoo with poor accesses and low bird densities. On the contrary, we encourage the use of technical improvements for avifaunal monitoring such as GPS/ARGOS or GSM/ARGOS devices for different species. Cooperation among developers to fund marking schemes for different projects nearby is highly advisable.

## Benthic communities on old gas platforms as predictors for new offshore wind farms

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Offshore structures in the Southern North Sea provide a habitat for a range of species such as anemones, soft corals, edible crabs and other animals not found elsewhere on the predominantly sandy seafloor. With the development of large amounts of offshore wind farms, new habitat for these species is provided. Extensive monitoring programs are conducted on the artificial reef effect of these wind farms in the Southern North Sea. However, due to the young age of the studied wind farms, still very little is known about the species community of these structures on the long term. With an expected life span of 20 to 40 years, the long term artificial reef effect of offshore structures is relevant for assessment of the impacts on the North Sea ecosystem. Offshore oil and gas structures provide similar structures and have been present over 40 years. Studying the community structure of these platforms gives insight in the long term effects of artificial structures in the North Sea.

To evaluate the effect of artificial hard substrate deployment, we have been sampling the fauna on gas platforms in the North Sea. Our poster presents the preliminary results from the inventory of the L10-A gas platform built in 1975 in the Dutch part of the North Sea. The platform is located at 53°24'7.49"N 4°12' 6.93"E, 27 nautical miles North East of the Wadden island of Texel at a water depth of 30 meters. The epifauna on the platform was sampled by a scientific diver using a surface supplied airlift sampler and an inventory of the mobile demersal megafauna was made from visual observations by a scientific diver and the analysis of ROV images created for technical inspection by the platform operator. Preliminary results show a depth related zonation in the community of the platform. From the intertidal zone to a depth of 20 meters the fauna is dominated by a *Mytilus edulis* and *Jassa* spp. mix changing to *Metridium senile*, *Alcyonium digitatum* and *Tubulariidae* in the deeper parts. Mobile demersal megafauna observed in situ by the diver and on ROV video images show *Cancer pagurus* and *Necora puber* as the dominant species. Similar distributions have been found on offshore wind turbine foundations.

With the inventory of this first platform complete, we will focus on additional platforms in a transect of increasing distance to shore. It is expected that species zonation and composition changes along this line, depending on total water depth, light penetration and the availability of food.

## WREN Hub – International collaboration to reconcile wind and wildlife conflicts

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Interactions between land-based wind farms and wildlife continue to raise concerns and impede development of projects in many nations at the same time that similar concerns over interactions have affected European offshore wind farm expansion and are emerging as concerns for the development of early offshore wind farms in the US. As research into these interactions continues, the ability to ensure that knowledge is shared broadly and that regions and nations build upon one another's efforts becomes increasingly valuable in efficiently moving siting and permitting (consenting) processes forward.

For land-based wind, potential effects on endangered birds and bats, as well as raptors such as eagles and the habitats that support them are of great importance to regulators (consenters) and stakeholders internationally. Concerns for seabird safety, and their use of critical habitats as well as effects of underwater noise on marine mammals from pile driving for offshore wind installation, head the list of concerns raised in the consenting process for offshore wind.

The Wind Committee, under the International Energy Agency, established WREN to examine environmental effects of wind development. WREN seeks to establish a collaborative space for interaction among wind researchers, developers, regulators and stakeholders, known as WREN Hub. The Hub is supported by a robust IT platform that features a knowledge base of readily accessible scientific literature, reports, and other media on interactions of wind energy with the environment. The IT platform also supports the collaboration of key groups internationally by providing an interactive space for preparing documents; sharing WREN-specific program information and news; posting upcoming wind energy research events; and connecting researchers, developers, and regulators to one another among the member nations.

## Colonisation of offshore wind turbines by marine insects

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Large assemblages of insects have been noted anecdotally on offshore wind farms around the UK, however very little is known about these communities; what species inhabit offshore structures, their abundances, and origin. Reports on the potential for offshore wind turbines to increase the movement of organisms and spread non-indigenous species make it vital to investigate any colonisation of offshore structures. The purpose of this study was to provide an initial look into the communities of marine insects inhabiting offshore structures and draw preliminary comparisons with coastal communities. A questionnaire showed that communities of insects are present on offshore wind farms around the UK. Field sampling found insects on offshore wind turbines and on another offshore structure; every individual was taxonomically identified showing six different families of insect present on offshore structures. The different taxa found are discussed along with differences in abundance and species richness of insect communities between offshore and coastal man-made structures. Implications for spread of invasive species are considered as well as other potential positive or negative ecological consequences and suggestions for future work.

## Activity of bats in different altitudes at wind measurement masts and wind turbines

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As a result of bat call recording in wind turbine nacelles, we know a lot more about the activity of bats in high altitudes and their risk of collision.

In our study we investigated which species appear and how frequently they use different altitudes.

Data were collected using ultrasonic detectors recording bat calls at wind measurement masts and wind turbines at different heights. The number of recordings was used as a measure for activity. Ultrasonic detectors were placed near the bottom, medium height (corresponding to the lower tip of the rotor blade of modern onshore wind turbines), and top of the masts or towers at 100-145 metres.

At the lowest altitude we found the highest flight activity and seven different genera of bats were recorded. The genera *Barbastella*, *Myotis*, and *Plecotus* were only detected at this low level. At medium height, the recorded activity noticeably decreased in comparison to the bottom level, and recordings at the highest level were diminished even further. Only four genera of bats were recorded at the top level: *Nyctalus*, *Eptesicus*, *Pipistrellus*, and *Vespertilius*.

Additionally, we compared data from numerous wind turbine nacelles in altitudes ranging from 75 to 145 metres, showing bat flight activity declines with increasing altitude.

Our study confirmed only some species bear a high risk of collision with wind turbine rotors. Based on our data, we expect bat fatalities will decrease with the development of higher wind turbines in the future.

## Bat mortality at a solitary coastal turbine in Delaware, USA

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High bat mortality has been an unforeseen side effect of the rapid growth of the wind energy industry; this high mortality has necessitated the development of mitigation strategies to reduce mortality while minimizing turbine downtime. We conducted a post-construction assessment survey of bat activity and mortality at a solitary wind turbine located along the shoreline near the Delaware Bay and Atlantic Ocean in Delaware, USA. Here we present the results of our carcass monitoring and mitigation study for the 2011- 2014 flight seasons. We also conducted acoustic monitoring surveys during this period; analysis is ongoing and results will be presented at a later date. Our objectives were to assess direct mortality caused by the turbine and evaluate the effects of an increased cut-in speed as a mitigation technique. From March 2011 until December 2012 we conducted daily searches from 1 March - 31 October, with weekly carcass searches during the remaining months. From 1 July - 15 July 2011 we conducted carcass searches every three days. During 2013 - 2014 we also conducted daily searches from 1 July - 31 October. This timeframe corresponds to the local period of bat migration and when we had observed the greatest presence and mortality. For 2011 - 2012, we found a total of 68 carcasses with no mitigation protocol; however, the turbine was not operational for the entire month of July 2012. From 1 July - 31 October 2013, we raised the turbine cut-in speed from 3m/s to 5 m/s every other week from 2000 - 2200 h each night and found a total of 23 carcasses. During 2014 we alternated cut-in speed among 3 m/s (control), 4 m/s, and 5 m/s every three days from 2000-2200 h each night from 10 September - 31 October; as of October 5, 2014, we had found a total of 14 carcasses. During 2013 we observed a 90% reduction in mortality during weeks the cut-in speed was raised. Our data suggest raising cut-in speed for a limited time each night is a viable solution for reducing bat mortality while limiting turbine downtime.

## Are wind turbines near vegetation edges risky for local bat populations?

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With the saturation of open areas with wind energy parks, companies started to build turbines closer to forests and hedgerows. Such habitat patches are important for bats as breeding areas, particularly in intensively used agricultural landscapes that lack trees. Bats also use linear vegetation structures for commuting. Finally, bats may use the transition zone between arable fields and forests or hedgerows for foraging because of the so-called 'edge effect'. The 'edge effect' describes an increase in animal species diversity at the transition zone of two habitats. An increase in insect species diversity owing to the 'edge effect' might attract bats to such edge habitats. Therefore, we investigated if an 'edge effect' can be observed in bats at the transition zone of forest/hedgerows. Additionally, we assessed the geographical size of the 'edge effect' for bats in arable fields. Finally, we present species specific activity profiles relevant for the planning process of wind turbines. We assessed bat species activity and diversity from June to September 2013 in an intensively used agricultural landscape, the Uckermark region in the federal district of Brandenburg, Germany. We recorded bat calls using automated ultrasonic recorders set up at 4 distances (0m, 50m, 100m, 200m) along a transect perpendicular to vegetation edges at 5 forest-field and 5 hedgerow-field sites. We analyzed all recordings manually using the software Avisoft SASLab Pro referencing published literature on bat species echolocation calls and their identification. Using linear mixed effect models in R we analyzed the influence of distance to the vegetation edge on bat species diversity. The species specific activity levels have been analyzed using generalized linear models. Our preliminary results show an edge effect pattern for bats at both forest-field and hedgerow-field sites. More precisely we found most bat species (e.g. *Pipistrellus nathusii*, *P. pipistrellus*) being highly active directly at the vegetation edge. However, the activity of these two species dropped with increasing distances to the edge. In contrast to this, *Nyctalus noctula* showed an almost constant level of activity at our recording points, irrespective of distance to the forest or hedgerow structure. Our data suggests differences in species-specific use of landscape features and highlights the importance of edge habitats for bat species diversity in agricultural areas.

## Is the modification of safety lights a suitable mitigation measure to reduce bird collisions at offshore structures?

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The use of offshore wind energy increased dramatically in the last years. In the future, several thousand turbines alone can be expected in the German North Sea. For reasons of shipping and aviation safety, the structures are equipped with lights that brightly illuminate the wind park area during night-times. Bird collisions happen predominantly at night. During adverse weather situations, the buildings' lights attract birds. In the existing licences of the wind farms, possible restrictions are imposed to minimize negative impacts on migrating birds. The answer to the title question, if there are lights that attract birds less than others, could significantly support an environmentally friendly use of offshore wind energy.

A comparison of the sums of birds found dead at the research platform FINO1 before and after the construction of the nearby wind farm *alpha ventus* showed a significant decrease of dead birds after construction, while in contrast, radar studies revealed an increase of bird movements. *Alpha ventus* with its 12 illuminated OWT, converter station, and FINO1 in all obviously attracted more birds than the research platform did. It appears plausible that the birds gathered not only at the research platform but also in the entire wind farm led to decreased concentrations at single constructions. We assume that under favourable weather conditions for bird migration, the wind farm has little negative impact on migrating birds. However, under adverse weather conditions, *alpha ventus* and FINO1 might jointly attract more birds nowadays and lead to higher collision risk than formerly at FINO1 alone.

Light attraction and its possible influence on a bird's navigational skills are poorly understood. Further, the importance of intensity and colour of lights remain unclear or even contradictory.

To clarify this, we investigated which light combination attracts birds least. At the coast we equipped LED-floodlights with thermal imaging and video cameras in order to record birds' flight activities. Light colour, intensity, and blinking rhythm as well as simulated variations of international and national safety regulations could be adjusted automatically. We detected some 10,000 birds close to the lights. Additionally, we recorded flight calls and used radar on a trial basis. In our statistical models we took further factors like cloudiness into account.

## Bat activity above the forest canopy

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In some regions of Germany, wind turbines are frequently installed in woodlands. Forests are the most important habitat for a large number of bat species, and therefore bat activity and the collision risk at turbines is often presumed to be especially high at forest sites. Particularly in close vicinity to important roosts of forest dwelling bats, it is often recommended to apply a rather strict mitigation scheme to prevent frequent fatalities. However, bat activity above forests has not been investigated on a larger scale yet.

In a research project on bats and wind energy in forests, funded by the Federal Agency of Nature Conservation by means of the Federal Ministry for the Environment, we measure bat activity in different altitudes above the forest canopy as well as at ground level at different forest sites in Germany. Automatic detectors are installed at mobile and fixed masts up to heights of 100 m. The masts are placed in the vicinity of known summer and swarming roosts as well as at comparable control sites without roosts.

First results show that high flying species with high fatality rates, like *Pipistrellus* sp. and *Nyctalus* sp., are frequently recorded high above ground at forest sites. However, the number of recordings per site differs considerably. Next, we are going to analyze whether the presence of roosts promotes high bat activity at high altitude. The results can be used to recommend suitable mitigation measures at wind parks in forests.

To predict reliably the collision risk at forest places, more intensive studies are necessary. Exemplary, this study cannot account for the altered conditions after the installation of turbines. Heat emissions and turbulences can affect insect density and therefore also bat activity. Furthermore, the effects of modern turbines are difficult to predict in pre-construction studies due to increased turbine heights. To investigate general patterns of bat activity in high altitude, it would be important to collect and analyze data from pre- and post-construction surveys in forests from different geographical regions. To get a deeper insight, when and where which bat species occur, such a large data set is needed.

## Vindval – a programme of knowledge

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Vindval is a co-operation between the Swedish Energy Agency and the Swedish Environmental Protection Agency. The purpose of the program is to collect and provide scientific knowledge of wind power impacts on humans and nature.

The Swedish Energy Agency has extended the Vindval research program with a third phase. The agency allocates a total of 27 million Swedish kronor for the implementation of Stage 3. The commission of Vindval extends through June 30th, 2018.

Projects in Vindval Stage 3 will include follow up and analysis of experiences of environmental impacts in parks that are in operation. In addition, Vindval will work to increase the contact area against other countries, to get an effective knowledge transfer.

### Environmental impact assessments

The Vindval programme comprises, so far, of about 30 individual research projects and also four so-called works of synthesis. Syntheses are prepared by experts who compile and assess the collected results of research and experience - regarding the effects of wind power - within four different areas: Humans, birds/bats, marine life, and terrestrial mammals. The results of research and synthesis work will provide a basis for environmental impact assessments and for the processes of planning and permits associated with wind power establishments.

## Estimation of potential collision mortality of grey-faced buzzard, broad-occurring migratory raptor

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The grey-faced buzzard (GFB, hereinafter) is a common migratory raptor and their migration flights occur in various regions in Japan. Thus, building consensus on the acceptable level of collision mortality is needed to develop wind powers in many sites. But, that discussion is often perplexed due to lack of information on the size and geological structure of the population. Objectives of this research are; 1) to estimate a rough number of migrants and the mortality of the target species based on information available today, and 2) to compare the potential risk level between GFB and other concerned species. The geological area where GFB occurs in breeding/migration seasons was divided into 173 blocks by mountain ridges or sea straits. We applied existing reports on a prediction model of nest density and mean breeding success to estimate sub-population size in each block. Then, we counted the number of migratory birds which were expected to gather from upstream of each blocks. Density of wind turbines was also used for estimation of potential collision risk. Because population density and collision frequency of the white-tailed sea eagle's population wintering in northern Japan is relatively well known, it was chosen for comparison with GFB's potential risk and for extra portion of GFB's mortality.

Consequently, our result revealed that ca. 93,000 migrants of GFB are expected to pass through the corridor per season. We also revealed 0.23-2.18 GFBs per season might be killed during passage in 5 major choke points, under the assumption of the relationship between potential risk and actual collision frequency in the white-tailed sea eagle population. Although no collided carcass of GFB has been found yet, intensive carcass survey should be conducted especially at these points. Collision mortality at wind farms does not induce serious irreversible impacts on the migration population of GFB, despite uncertainties in the estimation.

Usually, avian fauna to be preserved contains various species which have different extinction risk levels and ecological traits. Therefore, too excessive allocation of effort to avoid collision mortality in a certain species may increase the risk on another concerned species. To achieve the optimal mitigation policy for many species under such circumstances, quantitative risk assessment and risk tradeoff analyses are useful for avian collision risk management.

## Towards improved estimates of bird collisions with wind turbines offshore and on land: Comparing and improving theoretical and empirical collision rate models

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Accurate estimates of the numbers of birds colliding with wind turbines are an important aspect in the planning phase of wind farms. Collision rate models (CRMs) are used as a tool to predict numbers of bird collisions for wind farm initiatives both offshore and on land.

At present, collision probabilities of birds in offshore wind farms are unknown. Estimates of the collision rate for offshore wind farm initiatives are therefore obtained by using theoretical CRMs, in which the collision probability is calculated based on the physical characteristics of the turbine and bird species in question. For the on-land situation, information on collision probabilities is available for different species (groups). This information is used in empirical CRMs to predict numbers of bird collisions for wind farm initiatives on land. Recently, we developed an updated empirical CRM, called the Flux Collision Model, in which recent insights and empirical data on avoidance and collision rates on land are included.

In this presentation we: 1) Introduce the empirical Flux Collision Model; 2) Use two case studies to compare, discuss and evaluate results of the empirical Flux Collision Model and the widely used theoretical SOSS Band model; 3) Address the question whether theoretical CRMs can also be used to predict collision rates on land and vice versa; and 4) Denote the issues on which future research should focus to improve the fidelity of the results of CRMs.

The choice as to which type of collision rate model to use, theoretical or empirical, depends on the available input information. Theoretical models can also be used on land and empirical models can also be used offshore. Lack of knowledge on avoidance rates hampers the predictive power of theoretical models, while lack of good quality (empirically based) collision probabilities limits the reliability of the results of empirical models. The accuracy of the modelling results relies primarily on the quality of the input information and it is this that limits the fidelity of the results rather than the theoretical details of the examined models. Therefore, future research should focus on gathering information on avoidance rates and collision probabilities in existing wind farms both offshore and on land.

## Web Mapping Services (WMS) of ecological data as a decision-support tool for wind farm licensing procedure and maritime spatial planning

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The Federal Maritime and Hydrographic Agency (BSH) is an important provider of maritime services in Germany and, *inter alia*, responsible for maritime spatial planning and the licensing of offshore wind farms in the German EEZ. Environmental impact assessment (EIA) is part of the licensing procedure to ensure protection of the marine environment. Beginning with the first EIAs in 2002, when only poor ecological information was available for the German EEZ, up to now with more than 35 completed EIAs and monitoring investigations during construction and operation of the wind farms a vast amount of ecological data (e.g. concerning birds, fish, marine mammals, and benthos) was gathered. As German EIA- and monitoring investigations are conducted by the wind farm operators, the data is subject to trade and commercial secrets.

Since the data collected is of great importance equally for scientists, other competent authorities, planners, and industry quality-checked products are now being provided via Web Mapping Services (WMS) within the “GeoSeaPortal” of the BSH. The products offered are based on aggregated data to ensure trade secrets of the companies. To ensure the high quality of the data, quality checks and WMS-products have all been prepared in the context of research projects in cooperation with scientific experts, for example, from the Alfred Wegener Institute or the Research and Technology Centre of the University of Kiel. The web services contain EIA- and monitoring data as well as research data.

The BSH’s “GeoSeaPortal” provides a central Internet access to comprehensive, multidisciplinary geospatial data covering sea and coastal areas, based on international standards. Users of “GeoSeaPortal” have the opportunity to combine these biological data with e.g. hydrographic data, data of planned and existing uses (CONTIS), or can load these data into the background of their local GIS-systems. The geodata infrastructure of the BSH is part of “GDI-DE”, the Federal Government’s national geodatabase. For ecological questions with relevance for approval, the “GeoSeaPortal” provides different web map services of the distribution of selected benthos and fish species, seabird species as well as density maps of harbour porpoises in the North Sea EEZ. All products are aggregated in an EU-standard grid, in order to allow compatibility with external products. It is planned that this data will be made available for download via Web Feature Services (WFS) in the future.

## A model for the prediction of bat collision rates at wind energy turbines

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In Europe, a widespread method to mitigate bat collisions at wind energy turbines is to stop the rotor during times with high collision rates. To do this efficiently, high collision rates need to be predicted in order to save bats from being killed. Also, periods with low collision risk have to be identified to minimize losses in energy production. We present a model that reliably predicts turbine specific collision rates as well as identifies times with low collision risk. The model is a hierarchical zero-inflated Poisson model that includes a Bernoulli model for collision risk and a Poisson model for the collision rate.

We developed the model based on a large empirical data set including daily carcass searches at 30 turbines during 3 months, and continuous recordings of acoustic bat activity and wind speed at the nacelle of the turbine at 70 turbines during 7 months. We corrected for the imperfect detection of carcasses within the model.

The model is particularly useful for predicting bat collision rates during times of the year with low bat activity and little empirical data on collision rates.

## Abundant mobile demersal megafauna at wind farm *alpha ventus* foundations (German Bight) – two years after construction

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Several thousand planned wind turbine foundations will substantially increase the amount of habitat available for hard bottom associated mobile demersal megafauna (MDM) in the German Bight (North Sea). To assess the effect of the large scale habitat creation on MDM-stocks, the foundations of the wind farm *alpha ventus* were systematically scrutinized by diving. Two years after construction, hard bottom species already reached 100 fold higher abundances at the foundations than at autochthonous soft sediments. The brown crab (*Cancer pagurus*) reached abundances of 2,300 at single foundations, whereas there were only 29 individuals at the reference areas of comparable sizes. The uppermost parts of the foundations were densely colonised exclusively by young *C. pagurus* – potentially functioning as a nursery ground. The adjacent sea floor was inhabited by adults. The stocks of predatory hard bottom species could multiply with the establishment of numerous foundations in the North Sea. Calculative, 5,000 tripods provide habitat for up to 275% more *C. pagurus* in the German Bight. The long-term settlement of MDM at the foundations of wind farms should be considered when assessing offshore wind power reef effects and environmental impacts.

## Bat activity at offshore wind farms in the Netherlands

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We conducted surveys in 2012, 2013, and 2014 to assess the presence of bats over the North Sea. During these studies, ultrasonic recorders were placed at three locations: The meteorological mast at the Offshore Wind Farm Egmond aan Zee (OWEZ), a wind turbine at the Princess Amalia Wind Farm (PAWP), and the IJmuiden meteorological mast, respectively 15, 23, and 75 km from shore.

Bats were recorded at all monitoring locations and most activity was noted at the IJmuiden meteorological mast. Most bat activity occurred late August and throughout September. Bat activity in spring proved to be much more restricted and there was only one observation outside the migration season (in July) at OWEZ. Bat activity was strongly associated with the weather conditions; virtually all bats were only recorded during nights with low or moderate wind speeds, no precipitation, and a high ambient pressure.

Nathusius' pipistrelle (*Pipistrellus nathusii*) was the most commonly recorded species. Noctules (*Nyctalus noctula*) and (probable) Particoloured Bats (*Vespertilio murinus*) were recorded occasionally and the Common Pipistrelle (*Pipistrellus pipistrellus*) was recorded only once. The pattern of occurrence indicates that the observations of Nathusius' pipistrelle refer to migrating animals. The Nyctaloid species were possibly migrating as well, but they could also be residents from the mainland which may use the wind farms as foraging areas. It seems unlikely that the observations of offshore bats referred to individuals who were accidentally blown off course by storms. There are no indications that roosting individuals have been present in the vicinity of the recorders.

To date, the presence of bats at sea has not been taken into account during the site selection and operational management of offshore wind farms in the Netherlands. Our observations, however, combined with offshore sightings and findings of stranded individuals on oil rigs and ships indicate that bats regularly occur over the North Sea. Therefore, bats should not be ignored when assessing ecological effects of offshore wind energy at the North Sea.

## A holistic approach to the assessment of effects of offshore wind farms on submarine seascapes, including geophysical and biological information

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The current standards for investigating and assessing the effects of offshore wind turbines on the marine environment (StUK4) in the German exclusive economic zone (EEZ) were issued by the German Federal Maritime and Hydrographic Agency (BSH) in 2013. Within this framework, the assessment of changes in landscape caused by offshore wind farms is limited to landscape elements that can be perceived from ashore. However, both the German federal law and the European landscape convention require the safeguarding of evolved landscapes and their specific characteristics. There is currently no holistic approach, nor an investigation standard, concerning structural changes of the submarine landscapes with their habitats. An area-wide exploration of submarine project areas before construction is carried out by multibeam echosounding and by analysing the sedimentary characteristics by side scan sonar recording. The goal of the present study is to establish methods for translating geophysical parameters into submarine landscape elements as distinct, geographical area exhibiting particular characteristics and qualities. Through merging geophysical, bathymetrical and biological information we describe the submarine seascapes in the sense of Alexander von Humboldt as the “total character of an area on Earth”. This assessment will play a very important role in safeguarding biological diversity, ecosystem productivity and functionality and the variety, singularity, beauty and recreational value of nature and landscapes which the Federal Nature Conservation Act (BNatSchG) seeks to achieve.

## Trans-boundary origin of noctule bats killed at wind turbines in Germany

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The rapid expansion of wind energy in many European and North American countries is widely recognized as an environmentally friendly alternative to conventional energy production, but may come at high costs for bats dying at wind turbines. Here we studied the geographical origin of noctule bats (*Nyctalus noctula*) killed at wind turbines in eastern Germany to illuminate the spatial range at which populations of endangered bat species might be affected by operating wind turbines. Therefore, we investigated carcasses of noctule bats (n=136) found below wind turbines applying a three-step approach that combined 1) the measurement of stable isotope ratios of non-exchangeable hydrogen in fur keratin of bat carcasses to categorize individuals as migratory or sedentary, 2) a linear mixed-effects model to identify temporal, spatial and biological factors explaining the variance in the measured stable hydrogen ratios and 3) isoscape origin models to determine the geographical breeding provenance of the migratory individuals. We found that the majority of the casualties were of local or regional origin, while 28% were identified as long-distance migrants, hence documenting that bat fatalities at wind turbines in Germany may affect local as well as distant populations. Furthermore, we recorded a relatively high proportion of females among the migratory specimen and observed more juveniles than adults among the local individuals indicating that the vulnerability towards lethal accidents at wind turbines is sex and age-specific. Migratory *N. noctula* were found to originate from distant populations in the Northern and Northeastern parts of Europe. Here, sex specific differences in the breeding provenance were detected, with the geographical range projected for the origin of female bats extending further to the North and Northeast than for males. The large numbers of endangered bats killed annually at European wind energy facilities call for immediate action to reduce detrimental effects on local as well as distant source populations. This study highlights the importance of implementing effective mitigation measures as well as developing species and scale-specific conservation approaches on an international level. The efficacy of local compensatory measures such as the installation of artificial roost boxes appears doubtful, at least for migratory noctule bats, considering the large geographical catchment areas of German wind turbines for this species.

## Rehabilitating injured animals to offset and rectify wind project impacts

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Injuries to wildlife are increasing as wind energy rapidly expands worldwide. According to recent estimates, annual bird fatalities number in the hundreds of thousands in the USA, and so do bat fatalities. The United States Fish and Wildlife Service recommend that wind energy developers mitigate for “collisions with wind turbines and associated infrastructure,” which include distribution lines and guy wires. An often-overlooked form of mitigation is rectifying project impacts through rehabilitation of injured wildlife. Surveys were recently sent to 27 wildlife hospitals that were located near significant U.S. wind energy projects, asking about injured wildlife brought from wind projects and how much it cost to treat them. Two wildlife hospitals responded so far, but more responses are anticipated soon. During 2010 through June 2014, 66 injured birds and 1 injured bat were received at the two responding hospitals, or 14 birds per year. Only 3 of the injured birds were released into the wild, and one was placed in a sanctuary. For each animal sent to the hospital, months of work and thousands of dollars were spent to aid in both recovery and humane euthanasia. More injured animals might be rehabilitated if found sooner. Searches for injured wildlife could rely on large-area scanning with binoculars, which would cost less than traditional fatality searches. In addition to rectifying impacts, wind energy funding could substantially offset impacts by providing the resources at wildlife hospitals needed to rehabilitate injured wildlife received from all anthropogenic sources of injury.

## Modelling the natural conditions and impact of dredging and dumping activities in wind farm concession areas

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According to Belgian legislation, a concession is required for the construction and exploitation of an offshore wind farm. A necessary part to obtain a concession permit is the writing of an Environmental Impact Assessment (EIA) of the foreseen activities. IMDC wrote the EIA of concession zones Rentel and SeaStar and is currently writing the EIA for the wind farm, Mermaid.

The description of the initial reference situation and the possible natural evolution of the subsurface is an important element of the EIA. In order to assess the autonomic evolution of the seafloor, IMDC set up a numerical model that simulates the natural tidal currents, wave action, and sediment transport in the concession areas of Rentel and SeaStar.

In addition, IMDC performed dredging plume model studies in the same areas in order to assess the impact of dredging activities on the background turbidity and suspended sediment levels. The studies focus on the excess sediment dispersion caused by the dredging and dumping activities related to the creation of the foundation pits.

Also, now that the tendency in cable laying techniques is shifting from jetting and ploughing towards trenching, the numerical modelling of dredging and dumping plumes is becoming increasingly important.

## A case study of cancellation of a wind power plant construction plan and environmental impact assessment by NGO in Eastern Hokkaido, Japan

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After the Great East Japan Earthquake in 2011, the Japanese Government stimulated the introduction of sources of renewable energy, such as wind power generation. However, in Japan there are not many places where the profitability for construction of wind farms is acceptable and the risk of bird collision and/or habitat abandonment is negligible.

On the Pacific coast of Nemuro city, Hokkaido, there is an area called “Fureshima”. Fureshima has a rich natural environment comprising of various environments, such as wetlands, grasslands, and forests. In addition, this area is the wintering ground of the Steller’s sea eagle. The white-tailed sea eagle is an endangered species, and only a few pairs breed in summer.

In February 2012, there was a presentation on plans to build wind farms in this area by a company. In opposition to the environmental impact assessment conducted by the company, we decided to conduct an investigation on our own. To evaluate the impact of the wind farm on sea eagles, we conducted a field survey where we recorded the flight route and altitude of sea eagles from May 2012 to June 2013. Using these data and GIS, Kitamura et al. (2013) established the generalized linear model that predicted the flight frequency of eagles in study meshes. According to the model, it was expected that eagles would pass about 3,500 times per year within the planned region (235 meshes). In particular, regarding the mesh with the highest estimated flight frequency, it was predicted that eagles would pass about 363 times a year at the height of blades of wind turbines. Estimated flight frequencies in meshes including cliffs and steep-sided hills were high.

As a result of predicting the annual number of collisions using the sphere shape model, 0.39 birds would collide with the wind turbines on an average and 1.01 birds in the worst case. In comparison with the number of annual collisions in eight wind farms, our prediction roughly corresponds to the third place (0.40 eagles) and exceeds the highest annual collision rate (0.94 eagles).

On the basis of these findings, we appealed for a change in the planned region to the relevant ministries and local government, including the operator of the construction project. The motions to reconsider the plan have been placed by the public, and it has become a major movement. In July 2014, the operator suddenly announced the cancellation of the construction project.

## Seabird displacement analysis for a UK offshore wind farm: Robin Rigg, Scotland

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Robin Rigg in the Solway Firth was the first commercial scale offshore wind farm in Scotland, operational from April 2010. Ornithological monitoring was undertaken using boat-based surveys prior to, during and after construction. This valuable dataset, spanning more than a decade, was used to compare the abundance and distribution of seabirds across development phases.

New statistical techniques developed in the UK as best practice methods specifically for the renewables industry were used to compare baseline, construction and post-construction monitoring (4 years). Analyses were implemented for a range of bird species: guillemot *Uria aalge*, razorbill *Alca torda*, gannet *Morus bassanus*, red-throated diver *Gavia stellata*, and cormorant *Phalacrocorax carbo*.

Most species showed a change in abundance and distribution across development phases, although this was difficult to attribute to the wind farm. Guillemots and red-throated divers showed declines whilst cormorants showed increases. Gannets changed little but abundance was generally low. Patterns of spatial distribution were important for understanding the context of these changes.

This approach to monitoring and analysis provided considerable improvements in certainty around potential impacts, ultimately allowing potential impacts to be understood in greater detail.

The patterns of change in abundance and distribution of these species highlights the need to re-examine the questions that are asked during impact assessment for development applications.

## Effects of collisions with wind turbines for population trends of three long-lived raptor species

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Because of differences in life history parameters, additional mortality is likely to affect some species stronger than others. Long-lived species, with often relatively long maturation times and higher survival, are expected to be stronger affected than short-lived ones. To obtain an accurate indication of the likely impact of additional mortality, it is important to predict the effects on the long-term population trajectory.

The described work has been carried out in a project funded by the German Federal Ministry for Economic Affairs and Energy (formerly the German Federal Ministry of Environment) - PROGRESS - Prognosis and Assessment of bird collision risks at wind turbines.

Using age- and stage-structured matrix models, we predict the long-term effects of additional mortality due to wind farm collisions for three long-lived raptor species: Common buzzard (*Buteo buteo*), Red kite (*Milvus milvus*) and White-tailed eagle (*Haliaeetus albicilla*). To achieve this, we used an extensive dataset on all bird collision-victims found during a survey across 55 wind farms, collected over three years in Northern Germany. In order to predict the effects of the additional mortality in different populations, we simulated a range of different scenarios of survival and reproductive output.

These data are crucial to predict long-term effects on the population level for the selected species. From many studies, only the collision risk in form of additional mortality is known, which is not informative for the population level. In our study, we predicted whether the population is at risk of declining because of this additional mortality. As the German government plans to increase the capacity, we also simulated this scenario including the planned wind farms. This study hence provides a good opportunity to predict the effects of this wind farm development in advance. Combined with a habitat-dependent collision analysis, we will be able to provide advice for potential management decisions.

## The fledging wind energy industry in South Africa: Progress and challenges in minimizing impacts on birds

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Until recently, just eight commercial-scale wind turbines were operating in South Africa. The introduction of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) in 2011 saw a flurry of proposals for wind farms and it is anticipated that around 400 turbines will be spinning by the end of 2014.

Conservationists needed to act quickly to ensure birds were given adequate consideration in what has been dubbed the green rush. BirdLife South Africa and its partners rose to the challenge. A specialist group was established to provide guidance, and a forum was created to promote communication among stakeholders. Best Practice Guidelines for impact assessment and monitoring were developed (and updated), and an avifaunal sensitivity map was produced.

Tools and guidance are of little value if they are not implemented and various strategies have been used to promote their uptake, with mixed success. A web-based tool to facilitate the exchange of information is being developed by the national government. The next challenge is to increase the consistency in how data is interpreted, and critically compare the specialists' recommendations with the results of post-construction monitoring.

South Africa has been relying heavily on the experiences of countries with more established wind industries, but as an emerging economy some of the opportunities and challenges faced are different. Although South Africa still has a way to go before it will be able to share scientifically rigorous data on the impacts of wind energy, the lessons learnt and the tools developed could help other countries just beginning the wind energy journey.

## Satellite-tracking swans and geese to determine cumulative effects of both offshore and onshore wind farms along migration routes

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Serial development of wind farms are an important consideration in determining the potential cumulative effect of these developments on populations, but the extent to which both offshore and onshore wind farms occur along migration routes has received relatively little attention. Satellite-tracking of Whooper Swan and Barnacle Goose migration in relation to wind farm development therefore was undertaken in 2006–2010, and more recently Bewick's Swans fitted with GPS/GSM loggers were tracked in spring 2014, to determine the frequency of movement across offshore and onshore wind farm footprints during a single migratory flight. Each species followed different migration routes from the UK, to breeding grounds in Iceland, Svalbard and arctic Russia, respectively. Preliminary results from the study found that 11 offshore wind farms and 81 onshore wind farms were ≤5km of the flight-lines for 50 Whooper Swans tracked from England and SW Scotland. Moreover, 42 wind farms sites (8 UK offshore/inshore sites, 19 onshore sites and 15 sites in Norway) either had Barnacle Geese passing over the site, or were ≤5km from the flight-lines for at least 5 geese tracked on migration, with a further 71 sites ≤5km for 1–4 geese tracked. Over 80% of 50 Whooper Swans tracks passed over the footprint of at least one proposed or operational onshore site, with a further 20–30% of birds tracked to / from SE England/SW Scotland passing ≤5km of a proposed or operational offshore wind farm, rising to 70% for birds tracked from NW England. All of 21 geese tracked to Svalbard passed ≤2.5 km of a proposed (planned, consented or under construction) or operational onshore wind farm sites in the UK and in Norway, and 40–50% of goose tracks passed across offshore wind farm sites. Of the tracked Barnacle Geese, 19% of individuals passed across a wind farm footprint once, 9.5% twice, 5% on three occasions, 33% four times, 14% five times and 19% on six or more occasions. The results emphasise the importance of ensuring that the full range of wind farms encountered during the annual cycle are taken into account on undertaking risk assessments for the development of wind farms along migration routes.

## Developing the next generation ultrasonic acoustic deterrent

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Wind turbines can negatively impact bats at facilities around the world, endangering bat populations and limiting the economic benefits of these species (e.g. controlling agricultural pests). Operational minimization (i.e. changing turbine operations during periods of high risk) has demonstrated consistent reductions in bat fatalities, but may not be applicable in certain regions (e.g., areas with consistent low wind speeds or extended periods of risk) or species. Since 2006, the Bats and Wind Energy Cooperative (BWEC) has pursued the development of ultrasonic acoustic deterrents as an alternative strategy to reduce bat fatalities at wind energy facilities. Preliminary lab and field results demonstrated a reduction in the ability of bats to capture prey items and an overall reduction in bat activity. In 2009–2010, testing at an operational wind energy facility indicated as much as a 64% decrease in bat fatalities at deterrent-equipped turbines. Despite the early success, further research and development is needed to optimize performance and placement, and quantify the effectiveness of acoustic deterrents. In August 2013, the BWEC hosted a workshop with technical experts to develop the next steps for acoustic deterrent research. Here, we discuss the proceedings from the workshop and the design changes being implemented to create a more robust and effective device that maximizes the range of ultrasonic sound at frequencies that can target multiple or specific species, including endangered species. This endeavor will be mutually beneficial to all stakeholders by providing an alternative minimization strategy for bats, comparable to operational minimization, while allowing for the maximum production of renewable energy.

## European Nightjar *Caprimulgus europaeus* - best practice mitigation measures during wind farm construction

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European Nightjar *Caprimulgus europaeus* are a crepuscular and nocturnal bird that breeds across most of Europe and temperate Asia. Nightjar are usually thought of as a bird of heathland, however in Wales they are found mainly in clearfell commercial forestry plantation. Recent renewable energy policy has encouraged large wind-power developments at commercial forestry sites throughout Wales and there has been some concern that these developments have the potential to impact on important Nightjar populations. Pen y Cymoedd wind farm, the largest on-shore wind farm in England and Wales, is currently under construction, in a large area of forest plantation in South Wales, and was identified as supporting an important population of Nightjar during the EIA stage of the development. As such it was vital to develop an appropriate mitigation strategy to minimise any risk of impact on Nightjar during construction through disturbance or damage/ destruction of active nest sites.

As Nightjar is a cryptic species with low levels of day time activity they provide significant challenges to nest site location through the observation of behaviour. In addition as they build no nest, the eggs are cryptically coloured and are laid on the ground amongst clearfell brash, searching for nest sites is no simple matter. In light of these complexities a two stage survey approach was developed to locate nest sites combining non-intrusive listening/ call back surveys along with capture and radio-tracking of individuals to nest sites. Listening and call back surveys were focused at those locations proposed for works within the Nightjar period (May/June – September) and were used to target subsequent capture efforts based on observed Nightjar activity. Birds were then captured through use of tape lure and mist net under appropriate license, ringed and tagged with radio transmitters fixed to one of the two central tail feathers. Individuals were then radio-tracked during daylight hours to locate nest sites and allow appropriate works exclusion zones to be implemented. This enabled exclusion zones to be accurately positioned and nesting success to be monitored, maximising efficiency in the implementation of mitigation; minimising disruption to works whilst complying with legislation and ecological planning commitments. Monitoring will continue throughout the three year construction period and during the operational phase.

## Acoustic assessment of bat activity at wind turbines: Comparing the performance of different bat detectors

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In Central Europe, acoustic monitoring of bat activity has become the most common method to assess the collision risk of bats at wind turbines. Often, acoustic data are used to develop turbine specific ‘bat friendly’ operational algorithms that reduce the collision risk.

A major problem of acoustic monitoring is that there are many different methods (e.g. monitoring at the nacelle vs. at ground level, different microphone setups) and different devices (e.g. bat detectors) used to conduct such acoustic surveys at turbines. As these methods and systems vary in their acoustic properties, the bat activity measured strongly depends on the methods/devices used. Precise estimation of bat activity is crucial to assess the collision risk and to develop suitable algorithms to reduce the risk of bat collisions, but also to avoid needless shutdowns of turbines because of algorithms that are too conservative. Here, we compare different methods and detectors that are being used to assess the acoustic bat activity wind turbines, in particular maintenance requirements, downtimes, acoustic properties, and bat activity level recorded.

We did acoustic surveys at the nacelle of 16 wind turbines in 8 wind parks in four geographical regions in Germany in 2012 using different systems simultaneously. We used Anabat SD1 (Titley Scientific), Batcorder 1.0 (ecoObs) and UltraSoundGate (Avisoft Bioacoustics) detectors. In the lab, we also measured the frequency responses and directional sensitivity of the detector microphones.

We compared the acoustic activity of bats as presence/absence data for 10-minute-intervalls and found that with the settings we used the relative activity of species and species groups was quite similar for different detectors but for most species or species groups Anabat SD1 and UltraSoundGate recorded bat activity that was twice as high as the activity measured with the Batcorder. This shows that for different detectors different models have to be used to precisely predict risk of collision for the bats and deduce suitable algorithms.

We found that the employment of different microphone types with different directional characteristics and the use of various detector settings (i.e. various detection thresholds) are one of the main reasons for different estimations of bat activity. We further discuss detection volumes of detectors deduced from frequency response measurements and methods for a consistent calibration.

## Determination of macro, meso and micro avoidance rates for seabirds using a novel combination of radars, cameras and rangefinders

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Reliable information on avoidance rates for seabirds at offshore wind farms is scarce although urgently needed. The Offshore Renewables Joint Industry Programme (ORJIP) Bird Collision Avoidance Study has therefore been launched by the Carbon Trust to improve the evidence base available with respect to specific collision and avoidance rates to inform impact assessment for new wind farm developments. The study has been carried out at the Thanet Offshore Wind Farm in the United Kingdom. The study is an integrated, multifaceted research programme enabling the investigation of avoidance behaviour and collision impacts at multiple scales. Since summer 2014, the project has been monitoring macro, meso and micro avoidance behaviour and collision impacts of seabirds using a novel combination of high-resolution digital (visual/infrared) camera, radar and laser rangefinder technologies. A TADS camera system is applied in digital communication with surveillance radar systems, within the Thanet offshore wind farm, and combined with laser rangefinders, surveillance and high performance radars at the periphery of the wind farm. The detection system within the wind farm has collected data at the species level on micro avoidance and recorded collision events automatically. The detection system at the periphery of the wind farm has collected detailed data on meso and macro avoidance and flight altitudes. By using observer-based radar and rangefinder tracking the most of the collected has been at the species level. Spatially explicit flight models have been applied to the monitoring results to allow for extrapolation of estimated responses and flight altitudes to other sites and regions with different weather conditions as well as to other projects with different lay-outs. The data collected during the ORJIP project, which will continue until the end of 2016, will improve collision risk modelling by providing more detailed and reliable information particularly regarding enable micro and meso avoidance rates for a range of seabird species.

## Integrated detection trials to improve the accuracy of fatality rate estimates at wind projects

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As avian impacts increase with the worldwide expansion of wind energy development, accurate comparisons of fatality rate estimates are needed to identify meaningful patterns that can lead to effective measures for reducing or minimizing impacts. The two key factors contributing to the accuracy of fatality rate estimation are (1) detecting as many of the available fatalities as possible and (2) accurately estimating the proportion of fatalities not detected during routine fatality monitoring. As part of a study to test the avian safety of a new wind turbine model we sought to detect most of the available fatalities by performing searches every 4.5 days on average. To accurately estimate the proportion of fatalities not detected we integrated detection trials into routine fatality monitoring by placing only 2-3 fresh frozen bird carcasses per week on randomized days at randomized locations within the search areas around wind turbines. We also left all trial carcasses and wind turbine-caused fatalities undisturbed where found, and we monitored their status. After 202 trial carcass placements over two years, we fit a logistic function to detection rates related to body mass ( $r^2 = 0.93$ , RMSE = 0.046):

$$D = \frac{1}{(1 + 9.6788 \times \exp(-1.59920 \times \log_{10}M))},$$
 where D = detection rate, or proportion of placed carcasses found, and M = body mass (g) classified into 11 size ranges that doubled successively from the smallest size range of 0-8 g. We found 50% of the trial birds upon the first search following placement, and we averaged 4 searches per detection. We averaged 4 searches per detection for birds weighing  $\leq 8$  g, 12.1 searches per detection for birds weighing 8.1 to 16 g, and decreasing numbers of searches with increasing body mass. Of the 122 (60%) placed birds ultimately detected, 78 (64%) were correctly identified to species, 9 (11%) were identified to a larger taxonomic group, 24 (20%) were identified as small, medium, or large birds, and 11 (9%) were misidentified to species, and the average numbers of days preceding these determinations were 7, 22, 29, and 59, respectively. Detection rates can be predicted by body mass at a given search interval, which is a useful tool for adjusting fatality rates, and one that prevents biases caused by interaction effects between separately conducted carcass persistence and searcher detection trials. Our findings also suggest that the common practice of performing "clearing searches" is likely ineffective, that searcher detection trials comprised of only one opportunity to find placed birds will inaccurately simulate detection probabilities, and that species identification declines the longer the time between carcass deposition and searcher detection. Cost-effectiveness of fatality monitoring can be improved by integrating detection trials into monitoring and by simplifying the representation of the proportion of fatalities not found.

## Water birds at inland wetlands and wind farms – a radar-ornithological pilot study at Ismaninger Speichersee, Germany, documents the need for buffer zones

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To predict the collision risk of birds with wind energy plants (WEP), it is essential to know where birds fly. This study supplements existing data on the impact of offshore-WEP by analyzing new data on the spatio-temporal distribution of flight movements of water birds and other taxa in the vicinity of an important inland water site.

We therefore operated a fixed-beam radar station at the Ramsar site “Ismaning reservoir and (former) fish ponds” near Munich, Germany, whose surroundings have recently been designated as reserved WEP-area. Continuous radar-recordings were taken for 52 days between May 29<sup>th</sup> and June 27<sup>th</sup>, and from July 15<sup>th</sup> to August 5<sup>th</sup>, 2013. During this period, the extrapolation of the recorded echoes revealed that more than 110 000 birds were flying over the planned WEP, i.e. within a distance of 2000 m from the shore and in altitudes below 200 m above ground. These birds would have been potentially threatened by a collision with a nearby WEP.

In general, flight activity peaked at dawn and during the night, and 45 % of all bird echoes were detected in the potential WEP collision altitude below 200 m above ground. Highest movement rates were recorded within this height layer during both day and night. Flight altitudes also differed significantly between day and night. During daytime, there were only few water birds and “others” flying above 400 m. At night, the flight activity extended up to altitudes of 2000 m.

The data were collected during the moult migration of 50 000 water birds. Similarly, these results may apply to inland waters that serve as important roosting or over-wintering sites for migratory water birds. The results also highlight that the buffer zone recommendations of Länderarbeitsgemeinschaft der staatlichen Vogelschutzwarten (2007) and Deutscher Rat für Vogelschutz (2012) for WEP around inland waters should be applied to reduce collision risk.

This poster is taken from the upcoming article Köhler, U., H. Stark, K. Haas, A. Gehrold, E. von Krosigk, A. von Lindeiner & P. Köhler (2014 in prep.): Wind farms and water birds at inland wetlands – a radar-ornithological pilot study at Ismaninger Speichersee, Germany, documents the need for buffer zones. Berichte zum Vogelschutz, 51.

## Yolk loss: A damage principle in fish eggs caused by concussions and shock-waves

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Electromagnetic generated low energy shockwaves used in experiments with embryos of Japanese medaka (*Oryzias latipes*) were causing histo- and cytopathological effects in embryonic tissue anlage. Not only shockwaves but also strong concussions and impacts lead to the main symptom yolk loss. Electron microscopy demonstrates that during shockwave applications the yolk syncytium layer (YSL) ruptures until different quantities of yolk mass are released into the perivitelline space. Consequently, the circumference of the yolk is decreased. The layers of the YSL (yolk lysis zone and cytoplasmic zone) are shifted and folded. Therefore the YSL cannot fulfil its task of digesting the yolk material. Neither nutrients nor developmental signals can be transmitted to the embryonic tissues. This leads to maldevelopments. A successful hatching is not possible in case of yolk loss. Serious concussions are created during pile driving activities for the installation of monopoles of offshore wind power farms. The pile driving impulses can even exhibit shockwave characteristics. It is to be expected, that yolk loss may appear in all sorts of fish eggs nearby pile driving sources due to the impulse noise. Yolk loss can be used as a standardized proof for effect thresholds during pile driving activities. That's why more examinations are necessary in areas of building offshore wind farms.

## Are geotextile scour protections of offshore wind turbines a source of environmental contaminants?

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Scour protections consisting of natural rocks and boulders are commonly used measures to enhance the stability of offshore wind turbines in European waters. As an alternative to natural lithogenic scour protections, geotextile sand filled containers consisting of synthetic polymers are increasingly used in offshore wind farms to mitigate erosive processes at the seafloor around turbine foundations. Plastic polymers contain a variety of chemical substances which have been added during the production process in order to improve the mechanical properties and durability of the polymer. Some of these additives are known to be hazardous to marine organisms and humans potentially causing endocrine disruption or cancer. So far, the release of hazardous chemicals from geotextile scour protections under *in situ* conditions in the marine environment has not been quantified. Under controlled laboratory conditions we conducted experiments with eight different geotextile materials commonly used for coastal protection at both limnic and marine shores. Our results showed that potentially hazardous plastic additives like plasticisers and UV-filters were leached out by shaking with seawater for at least 24 hours, indicating that geotextiles, employed in the marine environment for stabilization of sediments and anthropogenic constructions, release environmentally hazardous chemicals. Geotextile materials, especially nonwoven fabrics, used as scour protections at the seafloor around the turbine foundations can attract a diverse biota consisting of mobile and sessile invertebrates and fishes. It can be assumed that chemicals from the geotextiles accumulate in associated organisms. Environmental risk associated with contaminants leaching from numerous geotextile scour protections in huge offshore wind farms should be evaluated by *in situ* investigations including the impact of accumulated contaminants on the associated biota.

## Case examples of avian mortality due to collisions with wind turbines in Japan

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During the period from April 2001 to March 2014, 158 bird carcasses were found at wind turbines in Japan. Thirty seven of the carcasses were those of the White-tailed Sea Eagle in Hokkaido, making wind turbines a leading cause of death for this species in Japan. Two-thirds of these birds were juveniles or sub-adults. Of these eagle deaths, 57% occurred in early winter, 24% during spring migration, and 12% in the breeding season. Half were found atop coastal terrace cliffs, and others were discovered on coastal hills or seashores. This distribution suggests that many wind turbines in Hokkaido were installed within the core habitat of this eagle, which is along the coast. The Japanese Ministry of the Environment has suggested that many young eagles collide in early winter because eagles fly low (at rotor height) when traveling to and from feeding grounds, and younger eagles might become distracted and careless when they encounter fish carcasses in a fishing port or in an estuary.

Also found at wind turbines built in coastal areas were 12 carcasses of Gulls, including the Slaty-backed Gull; 44 carcasses of Black Kite; and 15 carcasses of Crows. Endangered species listed on the Japanese Red List were also found, including one Ancient Murrelet, one Golden Eagle, and one Steller's Sea Eagle.

Kitano & Shiraki (2013) found 52 of the total 158 bird carcasses. They conducted a survey of 17 months duration from July 2007; this has been the most scientific study in Japan to date. The members of the WBSJ recorded 36 fatalities during four casual studies. The remaining 70 carcasses of the total 158 discovered carcasses were found incidentally by passer-bys. Estimations of carcass persistence rate and searcher detection error have not been conducted in situ in order to estimate fatality rates in Japan, nor have accurate collision death numbers been calculated. Consequently, it is difficult to compare case studies conducted in Japan with those conducted overseas. Accurate calculation of the collision death numbers in Japan will be required in the future.

Because there is no legal obligation for wind turbine operators to conduct post-construction surveys in Japan, there is little scientific evidence indicating the impact of wind turbines. It should be made mandatory for operators to publish the results of post-surveys conducted using appropriate methods, so as to identify under what circumstances wind turbines cause bird collision deaths. These data should accordingly be used in site selection for future wind turbines.

## Using a military laser rangefinder to record flight behaviour of birds around a wind turbine in a topographically complex area

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In pre- and post-construction studies related to the construction of wind farms, flight behaviour of birds is often visually observed and flight altitudes are estimated by eye. However, depending on the distance of an observed bird, the estimation of flight altitudes is increasingly prone to estimation errors. Furthermore, there are increasing numbers of wind turbines planned to be constructed in topographically complex areas like alpine regions.

In order to investigate the flight behaviour of birds relative to a wind turbine in a Swiss alpine valley, we use the military laser rangefinder Vector 21 Aero of Vectronix AG. The laser rangefinder is connected to a notebook where the azimuth, elevation angle and distance of a flying object relative to the observer is saved. Out of these data, it is possible to calculate the flight altitude of birds and thus, the result is a three dimensional position of a flying object in the air-space. 3D flight trajectories are composed by linking a row of several positions of a single object. To visualize data, software was developed which converts data into geographical coordinates to be displayed on a map.

The observations are conducted during main migration season in autumn 2014 starting mid-August until end of October. The observations are focused on larger birds ( $\geq$  size of a thrush). Parameters of flight trajectories will be analysed using linear-mixed models to determine factors influencing the closest approaching point of birds in 3D relative to the wind turbine. Suitability and limitations of the laser rangefinder together with results about the flight behaviour of birds around the wind turbine in the alpine valley are discussed.

## X-band radar as a tool for evaluating the behaviour and movement of bats for wind-power development

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Describing the behaviour and movements of bat species vulnerable to wind turbines is essential for the objective assessment of the vulnerability of their populations to this expanding land-use. An assessment of the favourable conservation status of affected bat populations and its expected maintenance is an expectation for European countries. Current tools to describe the behaviour and movements of bats either have a good spatial resolution but exceptionally short ranges (typically 10-20m and usually <50m) and involve the direct observation using auditory or visual methods (e.g. reflective IR or emissive thermal cameras) and cannot often identify individuals, or are able to operate at larger ranges but have a poor spatial resolution such as conventional VHF telemetry. In this case individuals are identifiable but information about population behaviours is poor. X-band radar has the potential to describe behaviour and movement of large numbers of individual bats at high spatial resolution and at kilometre scales. We are evaluating the use of vertical and horizontal X-band radar to describe bat behaviour movements.

We use a mobile radar unit able to use X-band in both horizontal and vertical modes to evaluate the potential of this to quantify and describe the flight behaviour of bats.

In a vertical scanning mode we describe the altitude of bats close to a known noctule (*Nyctalus noctula*) roost, with substantial activity above 100m and individuals observed at 800m. We can clearly separate the dynamic behaviour of bats foraging at night from those bird species simultaneously present in the airspace at night (e.g. sleeping swifts, *Apus apus*). Current evaluation in a horizontal scanning mode is directed towards establishing the potential of radar to detect small and medium sized bats and distinguish bats flying close to clutter such as trees and hedge-rows.

X-band radar appears to have a number of powerful applications in the study of bats at wind-farms, especially in the description of behaviour and activity of bats at development sites in a BACI statistical design.

Substantial work is required to validate the method and this is proving to be more problematic for bats than with birds.

## Effects of pile-driving sound on larval and juvenile fish

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Concern exists about the potential adverse effects of underwater sounds generated by pile-driving during the construction of offshore wind farms. Loud impulsive sounds, such as pile-driving sound, can cause fatal injuries in fishes. Until recently, very little was known about the sound levels at which injuries or death occur in fishes. We examined lethal effects of exposure to pile-driving sound in different larval stages of 3 fish species (common sole *Solea solea*, European sea bass *Dicentrarchus labrax* and herring *Clupea harengus*), representing different swim bladder developments (no, small, open, and closed swim bladder). Furthermore, we examined lethal effects, injuries, and recovery from injuries in European sea bass juveniles. Controlled exposure experiments were carried out using the 'larvaebrator', a device that was developed to enable exposure of larval and juvenile fish to pile-driving sounds in a laboratory setting. The device consists of a rigid-walled cylindrical chamber driven by an electro-dynamical sound projector, in which fish can be exposed to a homogeneously distributed sound pressure and particle velocity field. Recorded pile-driving sounds could be reproduced at zero-to-peak levels up to 210 dB re 1  $\mu\text{Pa}^2$  (zero to peak pressures up to 32 kPa) and single pulse sound exposure levels up to 186 dB re 1  $\mu\text{Pa}^2\text{s}$ . The highest cumulative sound exposure level ( $\text{SEL}_{\text{cum}}$ ) applied was 216 dB re 1  $\mu\text{Pa}^2\text{s}$  (999 strikes). Survival was monitored during a 7 to 13 day period. For European sea bass juveniles, injuries were assessed directly after treatment and potential recovery from injuries was examined 13 days after treatment. In 2 of the 3 larval studies (common sole and European sea bass), the final experiments were preceded by pilot experiments, to enable a power analysis to determine the number of replicates required in the final experiments. Previous experiences were used to determine the number of replicates in the herring larval study and the juvenile study. The results of the larval studies showed no significant differences in mortality between the control group and the exposure groups (at  $\text{SEL}_{\text{cum}}$  up to 216 dB re 1  $\mu\text{Pa}^2\text{s}$ ) for any of the species or larval stages, suggesting that lethal effects of pile-driving might only occur at small range (<100m). The results of the juvenile study will soon be available. Our results will be discussed in relation to other recent research, to evaluate the current state of knowledge and to formulate future research goals.

## Flight altitudes of migrating Common Cranes *Grus grus* in relation to offshore wind farms

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Knowledge of fine scale bird flight characteristics is a prerequisite if we aim to comprehend potential impacts of man-made structures such as offshore wind farms on migrating birds. Soaring landbirds as cranes and raptors rely on meteorological conditions producing uplift, i.e. thermals, during their long-distance migrations. However, as thermals are normally not produced over water, these birds rely on more energetically expensive flapping flight when crossing large bodies of water where they usually fly lower, which make them more prone to higher collision risk with wind turbines. Tens of thousands of Common Cranes *Grus grus* breeding in the Scandinavian Peninsula migrate over the Arkona Basin in the southern Baltic Sea, where several large offshore wind farms are being constructed or planned. The objective of this study was to assess flight trajectories and altitudes of migrating cranes crossing the Arkona Basin and potential conflict with the planned offshore wind farms.

The data about cranes flights were collected using several methods: Coastal observation using laser rangefinders, radar and range-finder observations from the offshore FINO-2 platform, and very high resolution 3D telemetry of birds equipped with GPS transmitters. The collected data were related to topographic and meteorological variables and further used for modelling crane flights. The results indicate that flight altitudes of Common Cranes over the sea range from a few meters to more than 1000 m (at the initiation of the crossing, thereafter they descend) above the water. During headwind and tailwinds >10 m/s and poor visibility conditions the birds fly lower while during sunny and calm tailwind conditions they fly higher. About 80% of migrating cranes fly at potential rotor height of offshore wind farms in the middle of the Arkona Basin. The developed models improve our understanding about crane flight altitude and directions in different weather conditions and can be used as a practical tool when assessing potential impacts of future offshore wind farms.

The major knowledge gap for assessing the collision risk of cranes with offshore wind turbines is the unknown response of this species to offshore wind farms. Almost no observations exist about behavioral reaction and avoidance rates when migrating cranes approach a large offshore wind farm.



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