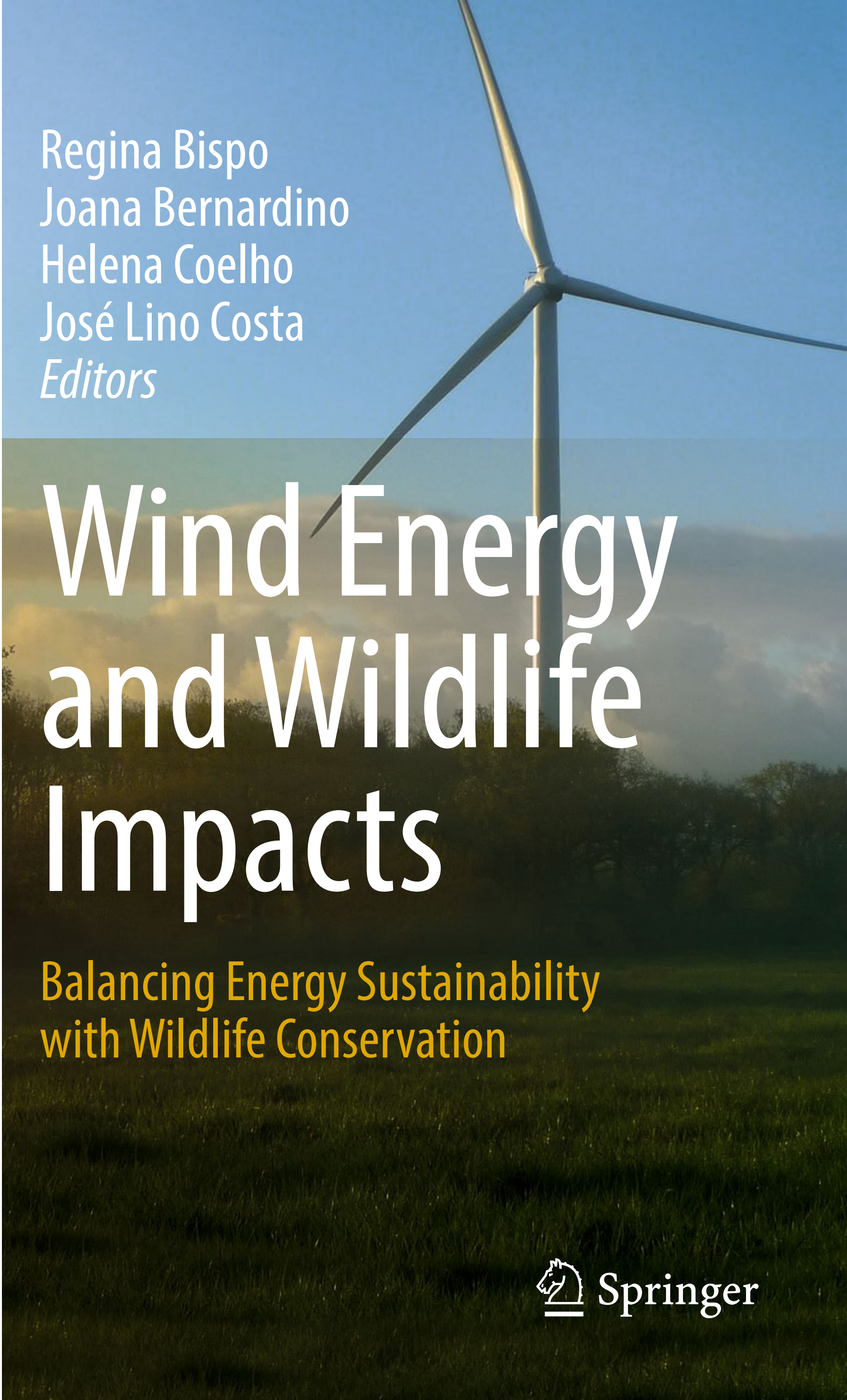

Regina Bispo
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Editors

Wind Energy and Wildlife Impacts

Balancing Energy Sustainability with Wildlife Conservation

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Preface

We are very pleased to introduce the proceedings of the Fourth International Conference on Wind energy and Wildlife impacts (CWW 2017), held on 6–8 September 2017, at the Centro de Congressos do Estoril, Portugal.

Wind power can be used in many ways and has several known advantages. It is renewable, does not involve carbon emissions, minimizes overdependence on traditional sources of electricity, and has domestic potential, among other important gains. However, the potential for impacts on wildlife is still a reality with potential to affect populations of many species, due to habitat loss and fragmentation, disturbance, nonnative invasive species, and increased mortality by direct collision. Hence, today's challenge is still to maximize wind energy's benefits while minimizing the risk to wildlife.

Aiming toward this goal, the International Conference on Wind energy and Wildlife impacts (CWW) gathers experts from all over the world aiming to promote the international cooperation among academics, researchers, and professionals, which, over the years, have contributed to building knowledge on this topic.

CWW started in 2011 being held since then biennially. The event has been continuously growing, and at the conference, in 2017, held at Estoril, Portugal, there were 136 presentations, 19 exhibitors, and over 340 registered participants, from 30 different countries all over the world. Oral conference presentations were organized in 15 parallel sessions, covering subjects related to species behavior (off- and onshore), fatality assessment, species fatality and vulnerability, mitigation, impact monitoring and risk assessment, planning and policy, population impact modelling, ecosystems and holistic approaches, and tools and technology. Conference program also included two sessions devoted to poster presentations. These proceedings volume provide a record of what was presented at CWW 2017. It contains 13 papers covering the subjects from both oral and poster presentations.

Many people have contributed to the organization of CWW 2017. We are most grateful to all members of the Organizing Committee that worked thoroughly for the success of this event and of the Scientific Committee for their commitment

in supporting scientifically the event. We are also grateful to all keynote speakers. Finally, we acknowledge all the participants on the panel discussion, as well to all speakers for their presentations and contributions to the conference.

Lisbon, Portugal — Regina Bispo
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Odivelas, Portugal — Helena Coelho
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The Role of Adaptive Management in the Wind Energy Industry

Andrea Copping, Victoria Gartman, Roel May, and Finlay Bennet

Abstract Adaptive management (AM) is a systematic process intended to improve policies and practices and reduce scientific uncertainty by learning from the outcome of management decisions. Although many nations are considering the use of AM for wind energy, its application in practice and in policy has been limited. Recent applications of AM have revealed fundamental differences in the definition of AM, its applications, and the projects or planning processes to which it might be applied. This chapter suggests the need for a common understanding and definition of and framework for AM and its application to wind energy. We discuss a definition of AM and technical guidance created by the United States (US) Department of the Interior's (DOI's) Adaptive Management Working Group. The chapter also examines how AM has been applied to wind energy development in several European nations and in the USA. The challenges and opportunities associated with implementation of AM for wind development are addressed, management actions in nations that exhibit attributes of AM are compared, and pathways to appropriate application and potential broader use of AM are explored.

Keywords Adaptive management · Wind energy development · Wind and wildlife interactions

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1 Introduction

All sources of energy have impacts on the environment. Understanding these effects is critical to helping countries make informed decisions about the relative costs and benefits of various energy solutions. Rapid and large-scale development of renewable energy and other developments challenge our ability to anticipate, verify, and mitigate impacts on the environment [1]. Although land-based and offshore wind contribute significantly to the renewable energy portfolios of many nations, many uncertainties remain about the potential effects of wind farms on wildlife populations and the habitats that support them [2] with particular emphasis on species of concern due to depleted populations. Continued expansion of wind farms on land and at sea requires tools that allow for the environmental management of wind projects in the face of these uncertainties. One tool that shows promise for decreasing uncertainty and providing increased insight into the environmental effects of wind energy development is adaptive management (AM) [3].

AM has been discussed since the 1970s as a means of facilitating potential decision-making processes for addressing uncertainty, managing natural resources, and directing research [4]. AM has been used during the process of developing wind energy projects in the United States (USA) and is under consideration in other countries, because it has the potential to reduce scientific uncertainty and inform future wind energy project planning and management decisions [3]. However, AM has not been irrefutably shown to be a practical management tool, because of the lack of consistency in its definition, preferred outcomes, implementation practices, and scales of relevance. This lack of consistency has resulted in a wide range of outcomes and effectiveness for managing environmental uncertainties associated with the wind energy industry [5]. It is important to note that striving for consistency in the application of AM during all aspects of wind energy projects may not be desirable because the relevance of AM to mitigating environmental impacts is likely to be specific to each individual wind energy project.

This chapter discusses the science of AM from an international perspective and its intersection with policies and management practices that are common in the nations collaborating in WREN (Working Together to Resolve Environmental Effects of Wind Energy). The exact effects and interactions of AM with the regulations or policies of any individual country cannot be inferred from these discussions.

2 Adaptive Management as a Concept

2.1 Definition of Adaptive Management

Lack of a commonly accepted definition of AM presents a challenge for its implementation. We have chosen the definition used widely by management agencies in the USA, developed by the US Department of the Interior (DOI) Adaptive

Management Working Group's Adaptive Management Technical Guide [6] and companion Application Guide [7], referred to here as the DOI guidelines.

AM refers to a learning-based approach, or learning by doing, that leads to adaptations of management programs and practices based on what has been learned [4, 7]. The most widely accepted definition of AM comes from the US National Research Council [8] and has been adopted and further described in the DOI guidelines, as follows:

> Adaptive Management is a decision process that promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process . . . [6, 8]

AM can be applied at the wind energy project scale, at which an AM approach is used to address scientific uncertainty and help inform management decisions related to specific projects (e.g., implementation of mitigation measures). Alternatively, AM can be applied at the planning scale using data and outcomes from individual and multiple projects to inform future regulations and development and management decisions [3]. The data collected may be similar for assessing scientific uncertainty and informing management decisions at both scales, but the spatial and temporal extent of monitoring data collection and analyses at the two scales may differ.

AM has been described as being passive or active [4, 9]. Passive AM describes the use of historical data to construct a single best estimate or model for response, by applying the best available science. Active AM uses more recent data to structure a range of alternative response models, and a management choice is made by taking into account the short-term performance and long-term value of knowing which alternative model best reflects the real-world situation.

Stakeholder engagement is an important additional ingredient that should be included throughout the AM process to generate initial research questions, review monitoring results, observe outcomes of management decisions, and ensure all affected individuals and organizations support AM objectives [6, 10].

2.2 A Question-Driven Approach

AM seeks to address scientific uncertainty and improve understanding of an environmental system using a question-driven, hypothesis-based approach. AM may not be suitable for application to all development projects. AM is not a trial-and-error process or a management approach that randomly implements alternative decisions if desired results are not achieved. Rather, AM maintains a hypothesis-based approach to meeting objectives agreed upon by the involved parties, and it typically uses quantitative or conceptual models to test hypotheses, provide management alternatives, and predict the consequences of management decisions. Post-installation monitoring of natural resource interactions provides data used to validate the models, address scientific uncertainties, and set a baseline for the managed environmental system [6, 8]. If a question-driven approach is not taken, the data collected may have limited relevance for use in validating models or supporting AM processes. A further set of challenges relates to the suitability of the experimental design for meaningfully addressing questions and the need to gather sufficient data to provide the levels of statistical power decision-makers require to implement AM.

2.3 Adaptability in the Face of the Uncertainty of Natural Variability

The AM process relies on maintaining a certain level of adaptability (flexibility) to ensure informed management decisions can be made in the face of uncertainty. As new information is gathered, management decisions may be amended to better accommodate the environmental system. Owing to the inherent natural variability of environmental systems and the inevitable measurement errors when measuring environmental interactions, uncertainty is a key attribute that must be accommodated by natural resource management. AM principles can be used to identify and understand natural variability and provide organizations with the knowledge and information to make informed management decisions in the face of uncertainty.

2.4 An Iterative Process

AM can be considered an iterative cycle, or “single-loop learning”. As information and data are gathered over time, management approaches and decisions can be adapted to better accommodate the ecological process or system being managed, thereby leading to better understanding of the targeted ecological system and improved management decisions. A further purpose of AM relative to wind energy is to optimize the use of wind energy while maintaining environmental safeguards. In practice, AM should enable greater wind energy development if the associated environmental effects are shown to be insignificant.

As discussed by the DOI guidelines, AM also promotes “double-loop learning”, or institutional learning. Figure 1 illustrates both single- and double-loop learning in the context of wind energy projects. The inner, single loop illustrates adjustments to individual projects based on data collected by that project (e.g., data to inform the use of mitigation measures at the project level). The outer, double-loop more likely takes place across multiple projects. It promotes the use of lessons learned from current and past projects to reconsider objectives and management alternatives and can potentially be used to inform future management decisions for other projects.

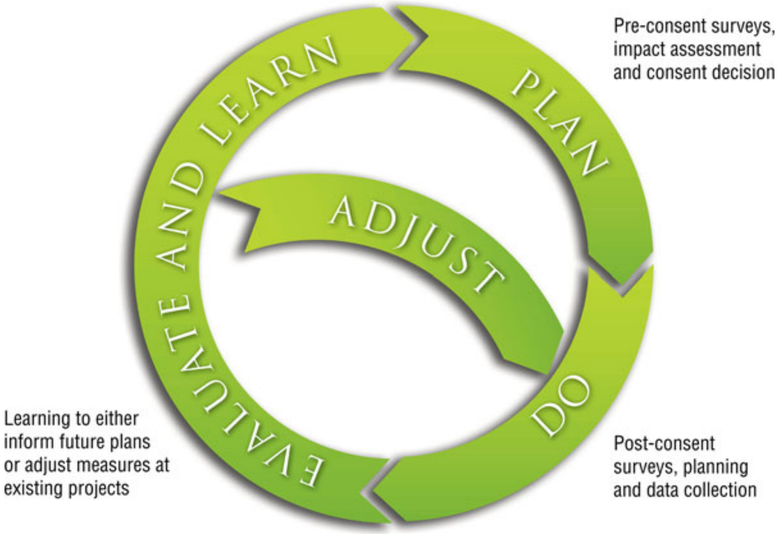

Fig. 1 Double-loop or institutional learning for AM. (Drawn based on Resilience to Transformation: The Adaptive Cycle [11])

2.5 Important Concepts Associated with AM

Several key concepts are critical for understanding the overarching objective of AM and how it is typically implemented.

- Scientific Uncertainty. The uncertainty that AM seeks to address is related to potential adverse outcomes associated with the development or operation of wind energy projects. However, AM may also be used to address the uncertainty associated with the overall effectiveness of certain mitigation measures or management decisions.
- Bounding. Bounding mitigation activities provides a level of financial security for project developers by limiting the amount of mitigation that may be required, while reassuring regulators that mitigation can be delivered if certain thresholds are surpassed.
- Scale. AM may be applied at the project scale to reduce the scientific uncertainty of an individual project or the effectiveness of particular mitigation measures (single-loop learning). AM may also be applied at the planning scale, where it takes place over multiple projects and may be used to collate information and monitoring data from different projects to inform the future management and permitting of wind energy projects (double-loop learning).

In practice, as mitigation activities are carried out, an AM approach could be used to evaluate the effectiveness of the mitigation actions, learn from experience, and reduce overall scientific uncertainty by informing more effective mitigation for use in future management decisions.

3 Application of Adaptive Management to Wind Energy Development

Each country and jurisdiction applies planning and management tools for the development of wind energy projects, based on the legal and regulatory system of that nation. Common tools or strategies applied to wind farm planning and management include the application of the precautionary principle [12, 13] and the mitigation hierarchy [14–17]. The application of AM principles to wind energy planning and management is not incompatible with these other management tools, but each must be carefully applied to ensure that a balance is struck between an overly restrictive approach that will not permit development of low-carbon energy production at all and one that protects key wildlife species and other environmental resources [5].

Although large volumes of post-installation data have been collected over two decades about interactions between wind turbines and wildlife for both land-based and offshore wind farms, many uncertainties remain along with a lack of understanding of basic processes that allow for effective mitigation of environmental effects. Similarly, monitoring data have not sufficiently informed future planning and management of wind farms over large spatial scales [18]. Often these data are considered to be "data rich and information poor", referred to as a DRIP condition [19]. These data may not yield sufficient information for a number of reasons, including the following:

- The data may not have been collected in a question-driven manner.
- The data utility may be undermined by issues of inadequate experimental design.
- The spatial scales over which monitoring has been carried out may not support the collection of samples to provide sufficient statistical power to meaningfully reduce scientific uncertainty.

AM can be applied at two scales for wind energy projects: the project scale and the planning scale. Data can be collected to reveal the impact of a single wind farm or a collection of projects on a population or segment of a population of concern. Because of the spatial and temporal scale of the data needed to understand large populations over wide geographic ranges, AM applied at the planning scale may be more effective at helping project planners understand how a wind energy project might affect a population of animals by using data from multiple projects over large geographic spaces. Conversely, the application of AM at the project scale may be limited for assessing population-level impacts, because project developers of single wind energy projects are unlikely to fund monitoring activities for an entire population that falls outside of the scope and range of their project, and the site-based results may have limited application to reducing uncertainty about the impacts on populations. Efforts are under way in the USA and other nations to broaden data collection to encompass areas larger than a single wind farm.

4 International Use of Adaptive Management

When reviewing international practices across a number of nations, the use of AM principles for wind energy projects was found to range from relatively frequent use in regulatory processes to no formal recognition or application of AM. AM is not a legal requirement in any of the countries reviewed. Case studies from Germany, the Netherlands, Norway, Portugal, Spain, Switzerland, the United Kingdom (UK), and the USA are described below (in alphabetic order).

4.1 Germany

In Germany, AM principles have been applied to several different projects. For example, the Ellern wind farm in Germany's southwest Rhineland-Palatinate attempted to mitigate the collision mortality of bats by curtailing turbine operation at wind speeds below 6 m/s from April to October. The mitigation was required locally, specified in the wind farm permit, and based on federal state guidelines. Data were collected during the first year of operation through carcass surveys and nacelle monitoring. After 1 year of operation, the monitoring data were compared with thresholds set by a group of stakeholders, including nature conservation organizations and the project proponent, and the curtailment methods were altered to ensure that the thresholds were met. Monitoring was only required for the first 2 years of wind farm operation, and subsequent adaptations to the monitoring plan were not intended [3].

Another wind farm located in North Rhine-Westphalia uses the cultivation of nearby farmland to trigger turbine shutdowns to avoid collisions with red kites (*Milvus milvus*) [20]. The birds are attracted to the newly mowed fields, presenting additional risk of collision with wind turbines. Shutdowns are required by permit under certain circumstances: during daytime periods if red kites nest within a 0.5 km radius of the turbines and for 3 days after cultivation activities. If monitoring of the surrounding area finds no nesting red kites within the minimum distance for 4 consecutive days, the measures are no longer required.

4.2 The Netherlands

AM principles have been used to adjust mandatory monitoring programs within projects for offshore wind farm projects. The offshore wind farm Luchterduinen includes intensive and regular contact between the competent authority and the wind developer to assess whether adjustment of the monitoring program is needed, based on monitoring results and information from other sources that have become available during the project [21]. Examples of major adjustments that have been made to the program include the addition of research on bats using bat detectors (which was not included in the monitoring program because the occurrence of bats at sea was largely unknown) and participation in the Disturbance Effects on the Harbour Porpoise Population in the North Sea project. The latter effort developed an individual-based model of the effects of underwater piling sound associated with installation of offshore wind turbines to support research into the effects of such sound on fish juveniles and larvae. These minor adjustments to the monitoring program led to a much more effective program than that originally scoped.

The use of AM principles among multiple offshore Dutch wind farms is becoming more common (double-loop learning). Currently, a third round of offshore wind farms is being planned in the Netherlands; each round builds on the knowledge acquired in the previous rounds to improve conditions and decrease constraints for offshore wind energy projects. The government implemented a new policy system for the third round; it improved implementation of AM by encouraging the selection of possible areas for offshore wind energy development, carrying out all preliminary environmental assessments, undertaking monitoring and research programs that will validate assumptions made in these assessments, and overseeing research into issues of financial importance to wind developers such as wind resource characterization, bathymetry, and sea bed characteristics [22]. Under this scheme, the government will draft decisions for each proposed wind farm site including all conditions and constraints for the development of a wind farm.

The third round consists of ten planned offshore wind farms of 350–380 MW capacity each. Wind farm site decisions will be drafted in five phases, one phase per two wind farms. Knowledge gathered during one phase will be applied in the next phase using an AM process. This process is new and just beginning to unfold, making it difficult to assess the extent to which AM will actually be applied. An evaluation at the end of 5 years will provide better insight into the questions about the use and efficacy of AM.

4.3 Norway

In Norway, the Nature Diversity Act could provide the legal mechanism for AM practices, because the precautionary and polluter pays principles are well established in the Act. However, in practice these principles are not used for wind energy and wildlife interactions because of the limited influence of the Environmental Agency in the consenting process. In addition, continuous tension exists between authorities and industry about who should be held responsible for financing monitoring and research on the environmental impacts of wind energy developments. There also is pressure to minimize total project costs in favor of profitability, which can act to compromise environmental considerations. Although

AM is currently not implemented in Norway, the renewable energy company Statkraft co-financed extensive research and monitoring at the Smøla wind farm from 2006 to 2017 [23, 24]. This effort included testing of mitigation measures in response to an official complaint from the Bern Convention to the Norwegian government concerning conflicts with white-tailed eagles (*Haliaeetus albicilla*). The investment has contributed to reducing the scientific uncertainty pertaining to both the extent of the impacts and effectiveness of mitigation measures.

4.4 Portugal

A good example of the principles of AM can be found at the Candeeiros wind farm located in the central portion of Portugal [25]. The Portuguese refer to it as an iterative approach to post-construction bird mortality monitoring. After 3 years of post-construction bird monitoring, the common kestrel (*Falco tinnunculus*) emerged as the species most commonly killed at the wind farm. As a result, the monitoring program was changed to study the kestrel population and evaluate the impact of the wind farm on this species. Although the common kestrel is not an endangered species in Portugal, the impact of the wind farm on the local population was considered significant, and this led to the development of a site-specific mitigation program (on-site minimization of bird mortality and offset/compensation). The environmental authorities and the wind developer concurred that this was the best solution for reducing kestrel mortality at the wind farm. The mitigation plan included planting native shrubs, enhancing habitat and scrub areas away from the turbines, and promoting extensive livestock grazing away from the turbines to enhance habitat heterogeneity. Monitoring of the kestrel population and carcass surveys continued in order to evaluate the success of the mitigation measures.

4.5 Spain

In Spain, environmental regulators, wind energy companies, and researchers may create agreements that are relevant to AM principles.

Wind farms located in La Janda (Cádiz, southern Spain) provide an example related to finding large numbers of dead birds due to blade collision [26–28]. After several meetings, researchers proposed a method for reducing avian mortality; it consisted of monitoring bird flight in the field, especially the flight of the more affected species such as the Griffon vulture (*Gyps fulvus*). When the wind farm operators detect a dangerous situation, they stop the turbines thought to be likely to harm the birds and restart them after the birds have left the area. Training was provided to operators to ensure accurate detection of collisions during carcass surveys. Daily monitoring for collisions was carried out.

The agreement reached by all parties was as follows: wind energy companies paid for the system; researchers carried out the data analysis and interpretation; and environmental agencies awaited the results before taking further measures. After 2 years, results showed a 50% decrease in mortality and a reduction in energy production of approximately 0.7% per year [27]. Since then, this monitoring method has continued and bird mortality rates continue to decrease.

4.6 Switzerland

Only recently have AM principles for wind energy projects been recognized as a means of improving upon the interpretation of impact assessments and management of bats around wind energy projects [29].

The Gries wind farm in Switzerland, planned to be the highest-altitude wind farm in Europe, has one pilot turbine that has been in operation since 2012 [30]. Three additional turbines are planned, but their potential impacts on migrating bat and bird species are considered to be highly uncertain. As a condition of the construction permit, a curtailment plan will be implemented to mitigate the project’s impact on bats. Bat activity will be monitored around the wind energy project for 3 years during spring, summer, and autumn; the resulting data will be assessed on a yearly basis in order to optimize the curtailment algorithm. Any operating adjustments will need approval by an operations commission consisting of stakeholders, the wind farm developers, an independent bat expert, and cantonal (local government) representatives. After 12 years of operation, the commission will reassess the project’s operating concept.

4.7 The UK

AM principles are used to manage wind energy and other renewable energy projects in the UK.

In a land-based example, at a 50 MW land-based wind energy project in the UK, developed in moorland habitat over 10 years ago, collision risk models were developed that suggested the facility could pose a risk for hen harriers (*Circus cyaneus*). Monitoring was carried out to determine how to effectively manage the heather moorland habitat to benefit the hen harrier through rotational burning, drain-blocking, etc. The monitoring has found the collision risk is negligible and informs annual decisions about how to best manage the moorland habitat [31].

Offshore, a number of wind farms have been consented in recent years in Scottish waters. Assessments of the potential impacts of wind farms on the marine environment are being used to develop a question-led approach to monitoring