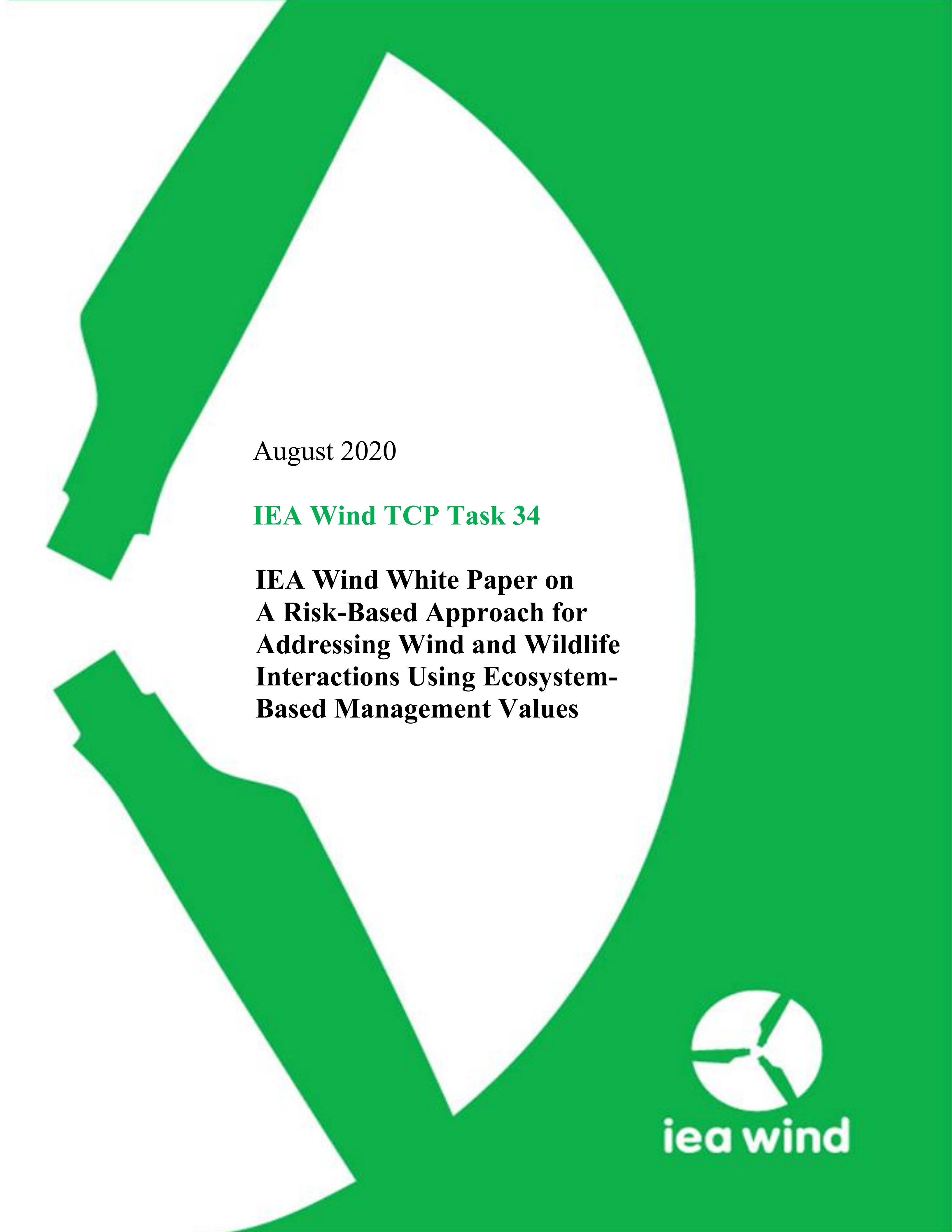

August 2020

IEA Wind TCP Task 34

IEA Wind White Paper on A Risk-Based Approach for Addressing Wind and Wildlife Interactions Using Ecosystem-Based Management Values

Technical Report

IEA Wind White Paper on A Risk-Based Approach for Addressing Wind and Wildlife Interactions Using Ecosystem-Based Management Values

Prepared for the
International Energy Agency Wind Implementing Agreement
by Task 34, also known as WREN (Working Together to Resolve
Environmental Effects of Wind Energy)

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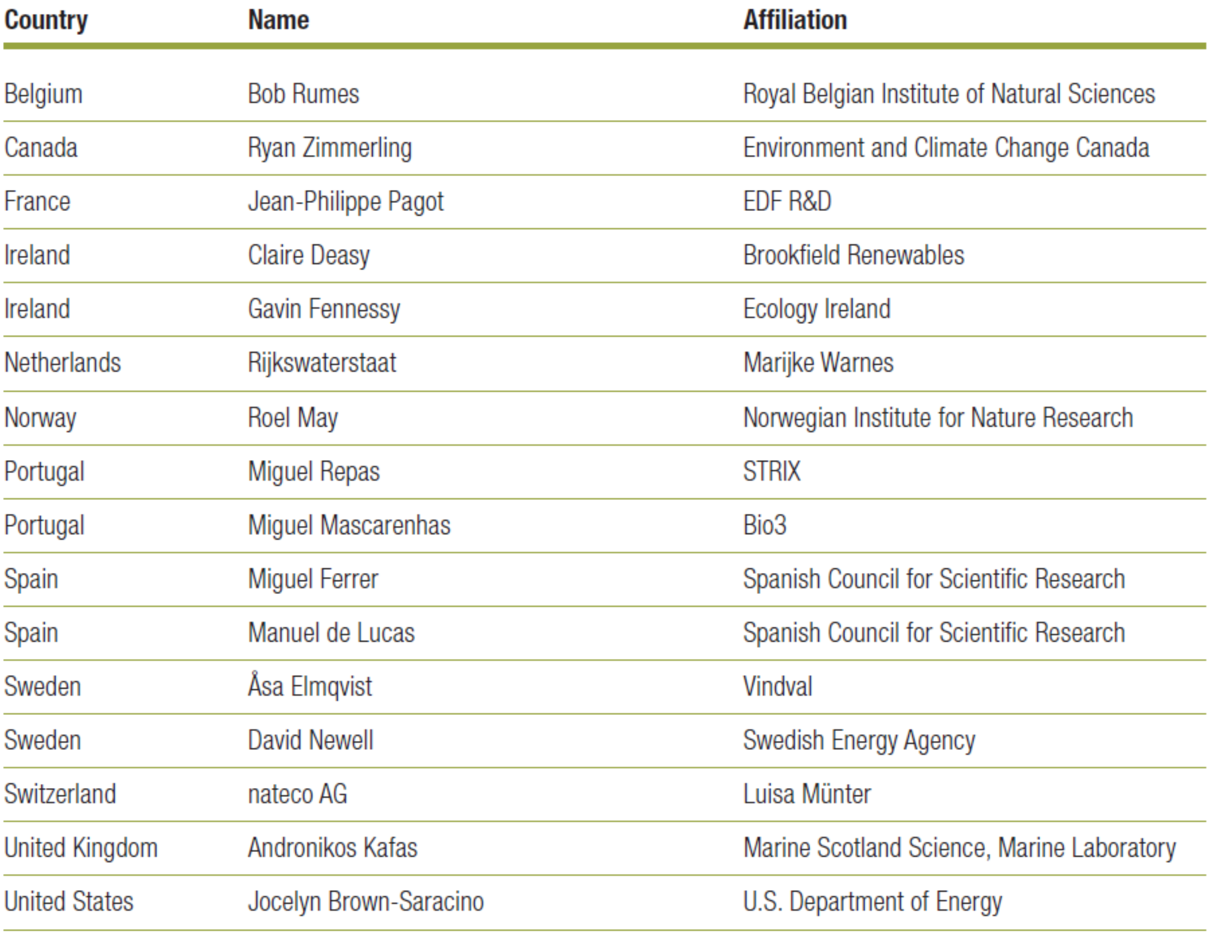
Preface

The primary objective of IEA Wind Task 34 (WREN) is to facilitate international collaboration to advance the global understanding of environmental effects of offshore and land-based wind energy development. Task activities are intended to contribute to advancing the knowledge base. A key strategy to achieve this goal is the development of white papers that will examine specific wind and wildlife topics where explicit information is not readily available within the existing literature, and to focus and facilitate discussion that will advance the state of understanding of global concerns within the wind energy community. This white paper on risk-based management is the third in a series of papers published through IEA Wind Task 34 (WREN).

IEA Wind Task 34 Participants (as of 12/31/2019)



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Abbreviations

ABMP	Avian and Bat Mitigation and Monitoring Plan
ADD	acoustic deterrent device
AHP	analytical hierarchy process
AM	adaptive management
BMP	Best Management Practice
BTA	bow tie analysis
CEA	cumulative effect assessment
CRA	comparative risk analysis
EBM	ecosystem-based management
EIA	Environmental Impact Assessment
EMF	electromagnetic field
EU	European Union
FMEA	Failure Mode Risk Analysis
FTA	Fault Tree Analysis
GIS	geographical information system
GPS	global positioning system
HCP	Habitat Conservation Plan
IFC	International Finance Corporation
INTACT	Innovative Mitigation Tools for Avian Conflicts with Wind Turbines
ITP	incidental take permit
LBW	land-based wind
LLC	Limited Liability Company
LOPA	layer of protection analysis
MBTA	Migratory Bird Treaty Act
MCDA	Multiple-criteria Decision Analysis
MCDM	Multiple-criteria decision-making
NARW	North Atlantic right whale
NINA	Norwegian Institute for Nature Research
NOAA	National Oceanic and Atmospheric Administration
O&M	operation and maintenance
OSW	offshore wind
OWA	ordered weighted averaging
PRA	Probabilistic Risk Analysis
RAG	Regional Advisory Group
RBINS	Royal Belgian Institute of Natural Sciences
RBM	risk-based management

ROD	Record of Decision
UV	ultraviolet (light)
WREN	Working Together to Resolve Environmental Effects of Wind Energy

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Executive Summary

Acceptance of wind energy development worldwide is challenged by stakeholders' concerns about potential effects on the environment, specifically on wildlife such as birds, bats, and (for offshore wind) marine animals, and the habitats that support them. Other issues of concern to communities near wind energy developments include social and economic impacts, as well as impacts on cultural and social values such as aesthetics, historical sites, and recreational and tourism. Lack of a systematic, widely accepted, and balanced approach for measuring the potential damage to wildlife, habitats, and communities continues to leave wind developers, regulators, and other stakeholders in an uncertain position. This uncertainty may lead to regulatory requirements for studies and monitoring programs that do not necessarily contribute to improved environmental protection. Regulatory requirements and data collection efforts around wind farms during construction, operation, and other project phases need to be more consistently linked to the actual risk posed to a range of animals and habitats. One such approach to accomplishing this linkage is risk-based management (RBM), which may provide value-added as a decision support system.

This paper explores the use of ecological RBM in wind energy development for land-based and offshore wind installations. The application of risk as a development and management tool is addressed, including multiple aspects of project risk, many of which are driven by or associated with ecological risk. The nature of how risk is taken into account in consenting/permitting wind projects on land and at sea are reviewed, and a series of risk management tools and approaches surveyed. This paper also explores the adaptation of ecosystem-based management to wind energy development through a series of case studies, and sets forth a framework and best management practices for applying risk-based principles to wind energy.

The analysis and review of RBM approaches presented in this paper may provide helpful insights for improved siting and consenting/permitting processes for regulators and their advisors, particularly in nations where wind energy is still in the early development stages on land and at sea. Wind project developers may benefit from understanding how regulators may approach consenting/permitting. Policy-makers may gain valuable insights into how wind farm development might be managed in future. Researchers and consultants may benefit from the concepts and suggestions that will improve access to insightful monitoring data from wind farms and will help to direct future data collection efforts.

1.0 Introduction

As acceptance of renewable energy becomes more common and technologies mature, the most critical factors for land-based (and increasingly offshore) wind energy project feasibility are not technical, financial, or limited by the wind resource. Acceptance of wind energy development worldwide is challenged by stakeholders' concerns about its potential effects on the environment, specifically on wildlife such as birds, bats, and (for offshore wind) marine animals, and the habitats that support them. Other issues of concern to communities near wind energy developments include social and economic impacts, as well as impacts on cultural and social values such as aesthetics, historical sites, and recreational and tourism activities (Gee et al. 2017; Gerkensmeier and Ratter 2018). Many of these issues are also associated with potential damage to natural resources and the environment. Often the best wind resource areas on land are also areas of great ecological importance (flyways or updraft areas) where birds take advantage of the same wind currents. Similarly, optimum offshore wind areas may correspond to migratory corridors for marine mammals and seabirds, as well as areas of importance for other sea uses such as navigation. The overlap of these areas may create hotspots of conflict, thereby disturbing migratory routes and causing injury or death to birds and bats caused by collision with turbine blades. This potential conflict leads to project risks that need to be identified, managed, controlled, and monitored throughout the project life. It is important to find strategies that are broadly acceptable to efficiently and proportionally de-risk these interactions and allow for management of residual risks.

Lack of a systematic, widely accepted, and balanced approach for measuring the potential damage to wildlife, habitats, and communities continues to leave wind developers, regulators, and other stakeholders in an uncertain position. This uncertainty often leads to regulatory requirements for studies and monitoring programs that do not necessarily contribute to improved environmental protection. Regulatory requirements and data collection efforts around wind farms during construction, operation, and other project phases need to be more consistently linked to the actual risk posed to a range of animals and habitats. One such approach to accomplishing this linkage is risk-based management (RBM), which may act as a decision support system.

1.1 Purpose of this Paper

This paper was developed to explore the use of ecological RBM in wind energy development for land-based and offshore installations. The application of risk as a development and management tool is addressed, including multiple aspects of project risk, many of which are driven by or associated with ecological risk. The nature of how risk is taken into account in consenting/permitting wind projects on land and at sea are reviewed, and a series of risk management tools and approaches are surveyed. Based on the review of these risk management approaches and the wind development needs of regulators, project developers, and researchers, the most appropriate risk-based tool─ecosystem-based management (EBM)─was chosen for further exploration. EBM was not derived from the need to address wind energy development, however; but this paper explores the adaptation of EBM to wind energy development through a series of case studies, as well as the development of a framework and best management practices (BMPs) for applying risk-based principles to wind energy. EBM was developed and derived from marine conservation and utilization principles; the framework for wind suggested in this paper is probably better suited for offshore wind than land-based wind, but lessons can be learned in both environments.

We believe this analysis will provide helpful insights into the application of improved siting and consenting/permitting for regulators and their advisors, particularly in nations where wind energy is still in the early development stages on land and at sea. It will also inform project developers of the guidance that regulators may wish to discuss. Researchers and consultants could benefit from the concepts and suggestions that will improve coverage and access to important monitoring data from wind farms. This paper does not address present or emerging policies for wind energy development in any particular nation, but it could be considered a helpful resource for those who may develop future policies, manage regulatory processes, or otherwise engage with the wind energy industry.

1.2 Risk and Risk-Based Management

Risk is a term that is widely used in many contexts; for the purposes of this paper risk is defined as the potential for a negative outcome, and is considered the intersection of the probability (likelihood) of that negative outcome, and the consequence (severity) of the outcome (Cardona et al. 2012). RBM is broadly defined as a system for the identification, assessment, and setting of priorities among risks, so that the appropriate level of resources can be applied to minimize, monitor, and control deleterious outcomes, taking into account the inherent uncertainties in the system. Managing risk is a process by which potential negative outcomes can be considered acceptable to society as informed by the identification, evaluation, and monitoring of the mechanisms and outcomes that make up the risks. There are many tools and constructs for identifying and managing risk for wind farms and other industrial developments that may meet the legislative intent for managing development. These resources include International Standards Organisation standard 31000 (ISO 31000; ISO 2018) and the International Finance Corporation (IFC) Good Practice Handbook for Cumulative Impact Assessment (IFC 2013), as well as scientific literature on these topics (Cormier and Londsdale 2019; Stelzenmüller et al. 2018; Cormier et al. 2015, 2018a).

The idea of "acceptable" risk is a very complicated one and cannot be fully addressed in this paper. This paper strives to describe a means of reducing the uncertainties related to wind energy/wildlife interaction data that drive risk. When considering the intersection of wind energy development and the environment, RBM examines and manages the potential negative outcomes that may befall birds, bats, terrestrial wildlife, marine mammals, other marine organisms, and the habitats and migratory pathways that support them. RBM has the potential to help ensure that wildlife protection measures are focused on the factors that pose the highest actual (as opposed to perceived) risk, while maximizing the production of energy.

The process for evaluating and managing ecological risk consists of several steps:

1. Find, recognize, identify, and describe the risk.
2. Analyze each risk.
    a. Comprehend the risk and determine the level of risk.
    b. Account for the presence and effectiveness of control measures.
3. Evaluate the risk by comparing the results of the risk analysis with established risk criteria and benchmarks to determine the significance of the level and type of threat (Steltzenmüller et al. 2017).

This paper focuses on ecological risks associated with wind energy development; but additional types of risk to the wind energy industry are inextricably tied to ecological risk, such that any measures that identify and manage ecological risk must consider that changes in ecological assessment or mitigation will affect those risks as well. For example, financial risks can be accrued based on the uncertainty of obtaining consents/permits in a specific length of time, as well as the potential for significant requirements for costly monitoring program requirements and mitigation obligations that may curtail energy production. Similarly, the potential for risk to the reputation of the wind energy technology developer, project developer, or project operator can be considerable, possibly tarnishing future development opportunities. Other types of risks for wind energy are often related to specific phases of wind farm development (e.g., regulatory or technical risks), while others continue throughout the life of the project. A more complete list of these risks can be found in Appendix A. This paper does not attempt to evaluate or balance these tradeoffs, but rather focuses on the assessment of ecological risk.

1.3 The Challenges of Consenting/Permitting Wind Energy Projects

Significant uncertainty persists around the potential effects of wind energy projects on the environment, particularly for offshore wind development (Sinclair et al. 2018; Copping et al. 2019; May et al. 2017). The uncertainty and paucity of data sets that confidently link wind energy construction and operation to deleterious effects, or that demonstrate no effect, often leads regulators and stakeholders to approach wind energy consenting/permitting processes conservatively, in ways that may be as stringent as the application of the Precautionary Principle, whereby the introduction of a new project whose ultimate effects are disputed or unknown should be resisted. Precautionary principles can form the basis for policy decisions in cases where the causes of potentially irreversible outcomes are poorly understood and where decisions to protect natural resources require certain and costly policy interventions that may not solve the problem as intended (Ricci and Sheng 2013). The Precautionary Principle is also described as the "no regrets" or "better safe than sorry" principle; it can be interpreted to mean that if a specific development or management action is surrounded by significant uncertainty and a potential negative outcome could occur, measures should be taken to avoid the negative outcome, at times by proceeding with extreme caution or not pursuing the project at all (Raffensperger and Tickner 1999; Kriebel et al. 2001; Köppel et al. 2014). Applying such precaution may lead regulators or stakeholders to conclude that birds or bats entering the rotor-swept area of a wind turbine are assumed to be fatally struck by a turbine blade. Mixed into this precautionary approach is the confusion about the potential effects of short-lived (but often high-impact) construction activities, such as pile driving at sea, associated with the ongoing but potentially less dangerous interactions of wind farms and wildlife during operational phases of the project. The overly cautious approach and misplaced focus on the interactions that have the highest potential consequences, irrespective of their likelihood, may shift focus and investments away from interactions that actually place wildlife at higher levels of risk. This could result in greater losses to wildlife populations already under stress from climate change, other anthropogenic activities that the development of wind energy counteracts, and natural factors such as disease.

2.0 Risk-Based Management Applied to Managing Industries and Natural Resources

RBM is reflected in many private and public sector planning and development programs and projects; some of the lessons learned from other industries are relevant to defining and implementing such a system for examining wind and wildlife interactions (Kuvlesky et al. 2007; Gregory et al. 2012). A number of risk-based methods have been used for environmental and natural resource management but have not yet gained widespread use in extending protection to wildlife, habitats, and ecosystem processes that might be affected by wind energy development. The most commonly used techniques are highlighted in Figure 2.1 and are described in more detail in Appendix B.

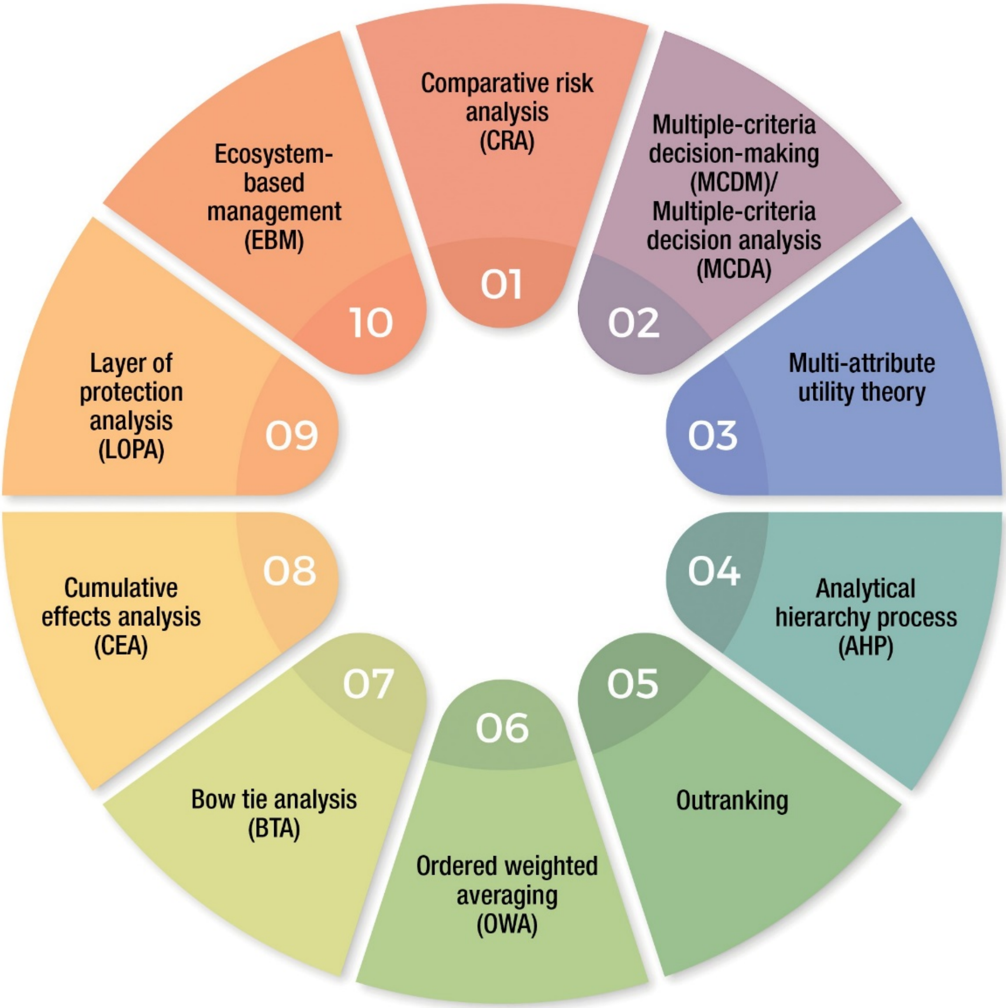

Figure 2.1. The techniques most commonly used for environmental and natural resource risk management.

2.1 Risk-Based Management Applied to the Wind Energy Industry

Where risk-based approaches have been applied to the construction and operation of wind farms, they are based on traditional risk assessment methods such as Failure Mode Risk Analysis, Hazard Identification and Risk Assessment, Fault Tree Analysis, Probabilistic Risk Analysis, and cost-benefit analysis. These approaches rely on a chain of linear cause-and-effect analyses focused on technical risk and reliability analyses, but they do not take into account environmental factors, or those that are associated with risk related to humans or organizations (Ashrafi et al. 2015). Risk-based approaches can be applied to all phases of the project life cycle, from siting and planning, design, construction, operation and maintenance, to decommissioning and repowering.

Risk-based planning methods have been developed and used for wind turbine operation and maintenance decision-making, although the associated studies focus largely on minimizing costs (Nielsen and Sørensen 2014; Florian and Sørensen 2017). In the United States there is currently no integrated risk analysis approach for offshore wind farms, but initial frameworks have been proposed. For example, Staid and Guikema (2015) proposed an initial framework based on a Bayesian belief network that can be used to estimate energy output, costs, and revenues for a given wind farm. While the examples they present focus on hazards related to weather (e.g., hurricanes, lightning strikes, extreme wave events), the framework itself includes both probabilities and related consequences of relevant hazards, enabling the user to develop an understanding of the largest risk factors and to envision steps toward effective risk mitigation.

2.2 Examining Environmental Risk-Based Systems for Wind Energy

Systems for examining environmental risk around wind energy farms have not been applied in a systematic manner for consenting/permitting. Risk assessments have not been used to determine the proportional level of investment in field data collection for baseline (pre-installation) assessment or post-installation monitoring programs. Systematic designs of mitigation to provide effective and efficient recourse for environmental impacts are also lacking (May 2017). There are some limited examples of risk-based systems of management for wind energy development:

- Marine Scotland, the regulator for offshore energy development in Scotland, employs the Survey-Deploy-Monitor approach to allow accelerated permitting and licensing for low-risk areas. This risk-based approach is used when potential effects are poorly understood to enable novel technologies to be deployed in a manner that will simultaneously reduce scientific uncertainty over time, while enabling a level of activity that is proportionate to the risks (Scottish Government 2018).
- A risk-ranking system developed in the U.S. considers the biological imperatives for the potential effects of offshore wind development on marine and avian animals and their associated habitats; the system also considers the protected or management status for each set of organisms in the U.S. (Copping et al. 2015). However, the system has not been implemented for permitting/consenting wind farms in the U.S. or internationally.

Adaptive management (AM)—a learning-based management approach used to reduce scientific uncertainty—has been identified as a tool for advancing the wind energy industry, but its practical application has been limited. AM has primarily been actively implemented in the U.S., but other nations have applied some AM principles. AM allows wind energy projects to adapt monitoring and mitigation over time, leading to improved decision-making (Hanna et al. 2016; Copping et al. 2019).

2.3 Ecosystem-based Management

While each of the risk-based approaches (Figure 2.1, Appendix B) provides useful insights into managing wind energy and wildlife interactions, few touch on all of the important aspects of ecosystems that land-based and offshore wind encompass. The risk-based approach that most closely addresses aspects of the complex ecosystems that make up the landscapes/seascapes of wind energy development is EBM. Although not fully applied to wind energy risk management, the concept of EBM has found a foothold in managing marine resources and fisheries (Long et al. 2015; Piet et al. 2019). EBM, which was first described in the 1990s (Christensen et al. 1996), takes into account human as well as environmental/ecological factors, using approaches that embrace holistic methods to include humans in an integrated view of managing resources while sustaining ecological integrity (Ruckelshaus et al. 2008; Barnes and McFadden 2008). EBM holds promise for application to the wind industry at sea and on land.

2.3.1 Ecosystem-based Management in the Marine Environment

EBM was applied to marine systems under stress following a publicly released statement by a number of leading U.S. marine scientists delineating the advantages of the management methodology and urging the U.S. government to embrace the concept for managing coastal and marine resources, as opposed to managing species by species (McLeod et al. 2005). The scientists argued that EBM

- emphasizes the protection of ecosystem structure and function, and the integrity of key processes;
- is place-based and focuses on a specific ecosystem and the range of activities affecting it;

- explicitly accounts for the interconnectedness within systems and recognizes the importance of interactions among many species, as well as key ecosystem services and other non-target species;
- acknowledges the interconnectedness among systems, including air, land, and sea; and
- integrates ecological, economic, and institutional perspectives, recognizing their strong interdependencies.

Additional studies support the ecosystem approach to management as providing advantages over the more common narrowly focused management approaches that have been used at sea and on land (Barnes and McFadden 2008). Among these advantages are the ability to ensure that EBM is

- geographically specific;
- adaptive over time as new information becomes available or as circumstances change;
- based on knowledge and uncertainties about the ecosystem;
- focused on multiple simultaneous factors that may influence the outcomes of management decisions (particularly those external to the ecosystem); and
- aimed at balancing diverse societal objectives that result from resource decision-making and allocation.

There are, however, challenges to implementing EBM as efforts are made to accommodate competing interests while sustaining productive, resilient, and healthy ecosystems (Barnes and McFadden 2008). In addition, applying EBM requires additional analysis for which data may be lacking, thereby potentially driving data collection costs related to wind farms higher. Balancing the advantages and challenges of applying EBM requires that implementation of EBM must be incremental and collaborative.

An assessment of the requirements for EBM concluded that data that characterize the ecosystem must be collected and collated in order to make informed management decisions (Barnes and McFadden 2008). Collection of information about social/cultural conditions, population dynamics, and socioeconomic factors is needed to supply the appropriate context for ecosystem data used for EBM. Finally, scientific research findings and knowledge must be articulated and translated in a useful manner to inform the consideration of EBM by policy-makers (Barnes and McFadden 2008).

In Europe, the Aquacross project (Aquacross.eu) evaluated the possible use of EBM as an integrative policy concept for the protection of aquatic biodiversity. It examined the degree to which the Nature Directives, Water Framework Directive, and Marine Strategy Framework Directive align with EBM principles and how they might work synergistically to protect aquatic biodiversity. While European Union (EU) environmental policies currently provide a sound legislative basis for implementing EBM, further streamlining and coordination across the wider spectrum of European policies is still needed to enable widespread application of EBM (Rouillard et al. 2018).

The National Oceanic and Atmospheric Administration (NOAA) is the U.S. government body responsible for managing living marine resources. More than a decade ago, NOAA introduced integrated ecosystem assessment as a process for developing the science to inform multispecies, multisector ocean management. An integrated ecosystem assessment forms the scientific basis for EBM and includes steps to set goals and targets; define indicators; analyze status, trends, and risks; and evaluate potential future management and environmental scenarios (Levin et al. 2009; Samhouri et al. 2014). Socioeconomic and biophysical attributes that maintain ecosystem structure and function, assess human activities and their interdependence with the natural ecosystem, and evaluate management alternatives that will maintain or improve the coupled social-technical-ecological system (Ahlborg et al. 2019) are identified through integrated ecosystem assessments (Figure 2.2).

EBM approaches to land-based wind energy projects are in the early stages of implementation internationally but have not been implemented in the U.S. In Canada, the development of a large land-based wind farm at Aristazabal Island, British Columbia, relied on multi-criteria decision-making based on a geographical information system (GIS) within an EBM framework for siting (Griffiths and Dushenko 2011). Where ecological risk assessments have been applied to land-based wind farms, they appear to focus on estimating wildlife mortality rates, behavioral changes, or interspecific differences in vulnerability, rather than the vulnerability and connectivity of all pertinent ecosystem components. In addition, a few studies have investigated the application of ecological risk assessments on endangered or rare species populations (Carrete et al. 2009).

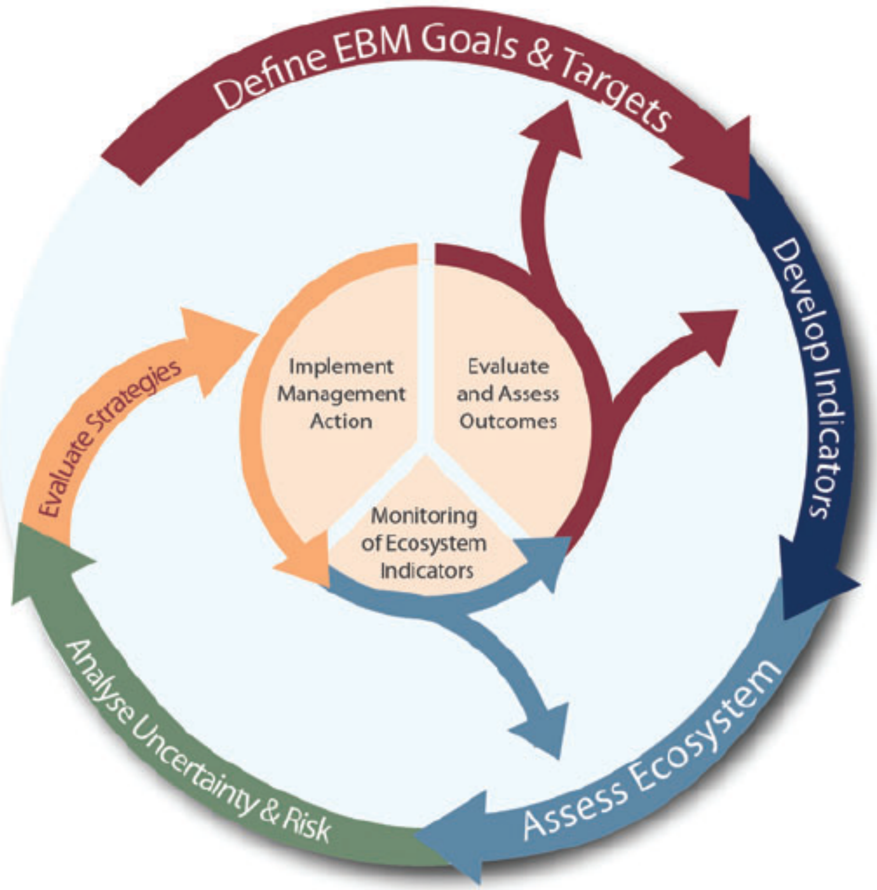

Figure 2.2. Conceptual schematic describing the cyclical, iterative values and interactions of integrated ecosystem assessments (Samhouri et al. 2014)

2.3.2 Effective Application of Ecosystem-based Management

There is a gap between the tenets of EBM and its practical application and appearance in management plans (Arkema et al. 2006). From a review of marine and coastal ecosystems, it is apparent that EBM can be described by three general and 14 specific criteria (Table 2-1). Based on the analysis, the ecological and social principles of EBM are only loosely incorporated into management plans and actions (Arkema et al. 2006). The gap between the theoretical basis for EBM and its incorporation into management plans suggests that EBM concepts need to be more effectively translated and that operational tools are needed to translate EBM principles into practice.

Table 2-1. EBM criteria derived from the scientific literature (adapted from Arkema et al. 2006).

Category	Specific Criteria	Requirement for Specific Criteria
General criteria	Sustainability	Emphasizes maintenance of one or more aspects of the ecosystem
	Ecological health	Includes non-specific goals for ecosystem health or integrity
	Inclusion of humans in ecosystem	Recognizes that humans are elements of an ecosystem and their education and well-being are important components of management decisions
Specific ecological criteria	Complexity	Acknowledges that linkages between ecosystem components, such as food web structure, predator-prey relationships, habitat associations, and other biotic and abiotic interactions, should be incorporated into management decisions
	Temporal	Incorporates the temporal scale and dynamic character of ecosystems
	Spatial	Recognizes that ecosystem processes operate over a wide range of spatial scales
Specific human dimension criteria	Ecosystem goods and services	Recognizes that humans use and value natural resources, such as water quality, harvested products, tourism, and public recreation
	Economic	Integrates economic factors into the vision for the ecosystem
	Stakeholder	Engages interested parties in the management planning processes to find common solutions
Specific management criteria	Science-based	Incorporates management decisions based on tested hypotheses
	Boundaries	Recognizes that management plans must be spatially defined
	Technological	Uses scientific and industrial technology as tools needed to monitor the ecosystem and evaluate management actions
	Adaptive	Continues to improve management actions through systematic evaluation
	Co-management	Promotes shared responsibility for management between multiple levels of government and stakeholders

Samhouri et al. (2014) recognize that integrated ecosystem assessments to support EBM have yet to be fully realized in the U.S., and they propose eight tenets (listed below) that can be adopted by scientists, policy-makers, and managers to enhance the use of integrated ecosystem assessments when implementing EBM. These tenets are not exclusive to marine systems; they also have potential application in land-based and offshore wind energy development.

1. Engage with stakeholders, managers, and policy-makers early, often, and continually throughout the different project planning phases.

2. Conduct rigorous human dimensions research.
3. Recognize the importance of transparently selecting indicators.
4. Set ecosystem targets to create a system of EBM accountability.
5. Establish a formal mechanism(s) for the review of integrated ecosystem assessment science.
6. Serve current management needs, but not at the expense of more integrative management.
7. Provide a venue for EBM decision-making that takes full advantage of integrated ecosystem assessment products.
8. Embrace realistic expectations about integrated ecosystem assessment science and its implementation.

The elements of EBM overlap with the ecological goals of protecting wildlife and habitats under wind energy development. Applying the advice of Samhouri et al. (2014) to specific ecosystem needs and interactions of populations and their critical habitats has been evaluated for potential effects from wind farm operations. This evaluation is articulated as a risk management framework that builds off EBM and helps fill in gaps that are pertinent to wind energy.

3.0 Developing a Risk Management Framework for Wind Energy

The risk management framework proposed here seeks to ensure that management decisions, monitoring program foci, and mitigation measures are proportional to the risk that wind energy farms pose to wildlife and habitats on land and at sea. The overall management actions associated with managing a wind energy development—from planning through siting, construction, operation, repowering, and decommissioning—are made up of many small and large management actions that together evaluate risks in a cumulative manner.

The risk management framework must be able to assess potential changes in entire ecosystems and ecological processes over time (e.g., long-term population trajectories of long-lived species such as bats) at the scale of a wind farm. To account for such complexity and associated uncertainty in decision-making, three central dimensions are important in assessing the overall risk (cf. Gardiner 2011):

1. Spatial dimension: Where does the risk occur and at what scale? For example, seasonal or diurnal migratory linkages to wind farm development at one location may have an impact farther afield.
2. Temporal dimension: When does the impact occur? For example, even though the severity of an impact may appear to be limited now, it may trigger an ecological tipping point for future generations.
3. Theoretical dimension: Which models can appropriately assess risk across space and time? For example, economic cost-benefit models tend to poorly predict effects in the long term.

The risk management framework provides further insights into the utility of RBM for reconciling the effects of wind energy on wildlife by

- identifying risks posed by wind farms for most phases of development;
- establishing criteria for evaluating the acceptability of those ecological risks;
- testing the goals and associated management actions through a set of case studies that represent wind energy development in multiple nations on land and at sea; and
- developing best practices for implementing RBM for wind energy development.

The principles and experience gained from EBM in the marine environment have helped guide and support this framework as the best fit among available RBM methods (Appendix B).

3.1 Ecological Risks Posed by Wind Energy Development

The range of potential risks from land-based wind farms to wildlife and habitats is well documented. Risks include collision risk to birds and bats (Barclay et al. 2007; Marques et al. 2014; Thaxter et al. 2017), displacement of flying and terrestrial animals from preferred habitats (Kuvlesky et al. 2007; May 2015), and disruption of migratory corridors (Kunz et al. 2007; Pelc and Fujita 2002), particularly for terrestrial and marine mammals (Lovich and Ennen 2013). The direct and indirect effects from offshore wind farm development have been less well documented, but they include similar risks of bird and bat collisions (Hüppop et al. 2006; Brabant et al. 2015); as well as harm to marine mammals, fish, and sea turtles from construction of bottom-mounted turbine towers (Tomsen et al. 2006); the potential for scour and sediment resuspension around the foundations of sea bottom-mounted wind turbines (Baeye and Fettweis 2015); and some evidence of displacement or barrier effects because of the presence of large offshore wind farms (McLean et al. 2006; Vanermen et al. 2015; Dierschke et al. 2016).

3.2 Goals for a Risk-Based Framework for Wind Farms

The design for managing risk at a wind farm, or a group of closely related wind farms, must support a range of wind farm-specific management actions that will cumulatively assign appropriate resources to and focus on potential effects. This allocation of resources must be based on the assessed level of risk for the range of specific interactions. The framework proposed here follows that of, but does not adhere strictly to, EBM criteria adapted from Arkema et al. (2006) (Table 2-1).

The purpose of the RBM framework, as adapted based on the EBM criteria, is not to scientifically assess the range of wind energy farms that are in development or operation around the world, but rather to take a small subset of farms where there is a clear intent to examine and maintain environmental integrity by protecting wildlife populations, ensuring the continuance of adequate habitat, and/or conserving ecosystem functions and services. The framework (

in the next section) is derived partially from the criteria for EBM, as modified by other RBM techniques applied to other industries and natural resources (Appendix B), and adapted to goals and objectives specific to wind energy development.

4.0 Wind Energy Development Case Studies

A range of case studies were chosen from land-based and offshore wind farms from WREN nations and other parts of the world, covering the range of development phases for wind energy from planning, permitting/consenting to siting, installation, operation, maintenance, repowering, and decommissioning. Each case study is briefly described and evaluated against the goals for RBM (

).

The range of international case studies represents several generations of development for land-based wind in some nations, newer offshore projects, and wind energy development in some regions that are in the early stages of development. Some of the case studies represent wind farms that have been in operation for many years, while others represent more recently commissioned farms, and others are still in the development stage. The case studies represent a range of development phases; several cases represent risk-based assessments, mitigation, or other management measures that span more than one of these phases. The case studies are summarized in Table 4-2. More information about each case study can be found in Appendix C.

Each case study has been examined to determine the degree to which it can be seen to meet the RBM goals for the framework, using a spread of case studies across the development phases for land-based and offshore wind farms (Table 4-3).

Table 4-1. Framework for ecological risk-based management as it applies to wind energy development.

Goal No.	Goal	Wind Farm Objectives Needed to Meet RBM Goals
1	Sustainability	Native animals, plants, and the habitats and migratory corridors that support them must persist and that take into account population-level effects.
2	Ecological health	The health and resiliency of the overall ecosystem is maintained or enhanced through management actions.
3	Inclusion of humans in ecosystem	A range of ecosystem services are accommodated in the area of wind farm development.
4	Complexity	Management decisions acknowledge linkages between ecosystem components, including predator-prey relationships, critical habitat needs for vulnerable populations, linkages of migratory corridors and critical habitats, and food web linkages at sea.
5	Temporal	Post-installation monitoring data collection and mitigation actions are applied seasonally as needed for key populations. Consideration is given to long-term cumulative effects on populations and habitats.
6	Spatial	Baseline assessments and post-installation monitoring of key populations cover spatial scales appropriate to the life history and home ranges of those populations. Consideration is given to the effects of wind farms that may occur at greater distances.
7	Economics	Operational constraints to protect wildlife and habitat allow sufficient power generation for wind farms to be profitable.
8	Stakeholders	Interested parties are consulted at the start of the development process and at all key points in time to determine sustainable operation of the wind farm.
9	Science-based	Management criteria are science-based with hypothesis-based post-installation monitoring plans.
10	Technological	Appropriate technologies and scientifically validated methods are used to monitor the potential effects of wind farm operation, and to assess the effectiveness of mitigation actions.
11	Adaptive	Adaptive management principles and procedures are applied to allow changes in post-installation monitoring efforts and mitigation actions when monitoring data indicate the need.

Table 4-2. Summaries of case studies.[(a)]

Case Number and Name	Country	Description of Development	Stage of Development	Management Actions
1. Crudine Ridge Wind Farm, New South Wales	Australia	37 turbines, 135 MW capacity	Under construction	Ecological approach to management, including adaptive management: 1. A Biodiversity Management Plan was developed as part of the overall Environmental Management Strategy that requires management of brush, plants, and habitat in the vicinity of wind farms, erosion control measures, brushfire management, and an extensive buffer around wind farms as a biodiversity offset. 2. A Bird and Bat Adaptive Management Plan was developed to provide baseline data on bird and bat populations, post-installation monitoring, documenting mitigation measures, pest control to discourage raptors around the wind farm, bat deterrence including lighting, and reporting to support adaptive management. 3. A Risk Evaluation Matrix Model was applied for risk of bird or bat collision or documented deterrence.
2. Norther Offshore Wind Farm	Belgium	44 turbines, 352 MW capacity	Operational	1. Siting: The layout of the wind farm was adapted to minimize navigational and resultant environmental risk. Obligatory collision-friendly foundation structures are minimizing the risk of oil spills. 2. During construction: Active mitigation was used to reduce the emission of high levels of impulsive sound during pile driving. The effectiveness of the mitigation methods was evaluated. 3. Uncertainty and knowledge gaps were addressed as part of an overarching long-term monitoring program funded by all nine offshore wind farms in Belgium. Studies include all ecosystem components and their interlinkages. 4. Multi-use of the area (co-use with either aquaculture or wet renewables) is part of the licensing conditions. 5. Adaptive management used to allow adjustment in mitigation measures based on monitoring results, which could result in either less or more stringent mitigation measures. 6. Uncertainty related to cumulative effect assessments (CEAs) was undertaken at the appropriate scale requires trans-national (regional) input and cooperation.

Case Number and Name	Country	Description of Development	Stage of Development	Management Actions
3. Smøla Wind Farm	Norway	68 wind turbines, 150 MW capacity	Operational, moving toward repowering	1. White-tailed eagle collisions are considered the greatest concern, also those of other bird species. 2. An adaptive management approach was used, in assessing needs for re-powering. 3. Research is conducted on the efficacy of updraft-based micro-siting of turbines (which was tested at another wind farm on the neighboring island of Hitra), painting blades and towers for better visibility, deterrence around turbines with ultraviolet (UV) lighting, and selective curtailment.
4. Candeeiros Wind Farm, Alcobaça/ Rio Maior	Portugal	42 turbines, 121 MW, estimated annual production of 345 GW	Operational, repowering	1. Post-construction monitoring showed high fatality rate of common kestrels. 2. Mitigation was conducted to decrease the attractiveness of the areas around the turbines and to increase food availability in areas outside the wind farm. 3. Adaptive management was used, resulting in monitoring data that showed a decrease in kestrel collisions, increased tracking of individuals using a Global Positioning System (GPS), and further changes in vegetation management around turbines.
5. Swiss Jura mountains, 13 distinct projects	Switzerland	145 wind turbines, spread over 2,000 km^2	Studies under way to support consenting and development	1. Sensitivity mapping is used to identify important sites for birds and bats, and to exclude wind energy development. 2. Priority areas for wind energy development and the level of conflict potential for nesting and migratory birds across the region are identified. 3. Studies of bats and birds, including nesting habitats and buffers, and predictive modeling for song birds’ migratory routes are conducted. 4. Collision risk and population modeling is conducted to determine the cumulative risks to protected bird and bat species. 5. Mitigation measures are used to reduce population-level impacts. 6. A stakeholder steering committee monitors wind project development and wildlife impacts. 7. Mitigation can be ramped up if monitoring programs determine that collisions exceed predictions.

Case Number and Name	Country	Description of Development	Stage of Development	Management Actions
6. Moray Firth Offshore Wind Projects, which entails 3 projects	United Kingdom	1. Beatrice: 84 x 7 MW turbines 2. Moray East: 950 MW installed capacity 3. Moray West: under initial consultation	1. Under construction, first electricity generation in 2018, fully operational in 2019 2. Consented in 2014, construction scheduled to begin 2019 3. Under initial consultation with an Environmental Impact Statement scheduled for later submission	1. Initial zonal assessment identified the Moray Firth area for offshore wind farm development based on GIS mapping that included a large number of constraints (including information about seabirds and marine mammals). 2. Each project assesses worst-case scenario cumulative impacts at the population level for potentially affected marine mammal and seabird populations. 3. Mitigation measures are incorporated through the Environmental Impact Assessment process to reduce the risks e.g., use of acoustic deterrent devices (ADDs) prior to pile driving to reduce the likelihood of marine mammals being injured by acoustics, use of fewer and larger turbines to decrease risks of collision and displacement effects on seabirds. 4. A Regional Advisory Group (RAG), made up of key stakeholders, agreed upon question-based monitoring that is undertaken by the project developers. The results can inform future worst-case scenario cumulative effects assessment, making it less precautionary and more accurate.
7. Sierra de los Caracoles Wind Farm	Uruguay	5 turbines, 10 MW capacity, additional 5 turbines proposed, 10 MW capacity	Operational and planning	1. Greatest concerns are about visual impacts and cultural resources. Other risks from the wind farm are not clear, but will be determined by monitoring. 2. Phased development, adaptive management, and landscape-scale management are in use. 3. With the initial 5 turbines, monitoring will determine their effects on birds and bats. 4. A phased approach will determine how 5 more turbines will be added, based on monitoring of the first 5. 5. Explicitly mentions the need to reduce scientific uncertainty. Note: During a 2009 field visit, a World Bank team found that the nacelle (gondola) for Turbine No. 5 had two round holes where the caps were missing (the other four turbines had all their caps). These holes can attract birds (such as the locally common American Kestrel *Falco sparverius*) to roost or attempt nesting within the nacelles, which is hazardous to the birds because of the close proximity to the rotors. One of the proposed mitigation measures based on these observations is to ensure the nacelle holes are not missing caps.

Case Number and Name	Country	Description of Development	Stage of Development	Management Actions
8. Block Island	United States	First offshore wind farm in North America. Five seabed-mounted turbines, each 6 MW.	Operational	First offshore wind development in U.S. 1. Siting and planning: Sited in wind energy area determined by the State of Rhode Island through the Ocean Special Area Management Plan. 2. Studies: Extensive baseline studies, post-installation monitoring of benthic habitats, birds, and bats. 3. Habitat protection: Horizontal direct drilling for cable through shallow water and intertidal area. 4. Construction: Monitoring for sound of piling at sea, and additional vessel traffic. 5. Operation. Turbines curtailed during fog.
9. Cape Wind Energy Project, Nantucket Sound	United States	130 turbines, 468 MW capacity	Planning and consenting process. Cancelled.	1. Adaptive management approach to monitoring and mitigation through an Avian and Bat Mitigation and Monitoring Plan (ABMP). 2. Mitigation plan focused largely on construction activities, including underwater noise reduction, marine mammal observers on vessels during pile driving, etc. 3. Broad consultation with stakeholders including Native American Tribes.
10. Iowa Wind Energy Project Portfolio, Iowa	United States	22 wind energy facilities with 2,020 turbines, greater than 4,040 MW capacity	Operational	1. Ecological approach, including adaptive management using a Habitat Conservation Plan (HCP) that focuses on bats and bald eagles under special protection; applying mitigation hierarchy to ensure these populations are not affected; and protecting and monitoring for other bat species and their habitats. 2. The projects examined as part of this analysis also provide financial assistance for the costs of monitoring and mitigation. 3. The adaptive management applies monitoring results to verify the effectiveness of mitigation measures and to reduce the uncertainty of wind energy effects in Iowa; and triggers additional monitoring and mitigation if annual collision mortality exceeds defined threshold limits. 4. The adaptive management framework allows for reduced mitigation measures if monitoring results show lower mortality than allowed, including less stringent mitigation measures such as blade feathering below the normal turbine cut-in wind speed.

(a) More complete information about each case study can be found in Appendix C.

Table 4-3. Assessment of the ability for each case study to validate RBM goals, by development phase and key management actions.

	Case 1 Crudine Ridge	**Case 2** Norther	**Case 3** Smøla	**Case 4** Candeeiros	**Case 5** Jura Mountains	**Case 6** Moray Firth	**Case 7** Sierra de los Caracoles	**Case 8** Block Island	**Case 9** Cape Wind	**Case 10** Iowa Wind Energy
Development Phase	Under Construction	Siting and Permitting, Construction, Operational	Operational, Planning for Repowering	Operational	Studies to Support Consenting	Operational, Consented, Consenting Consultation	Operational and Planned	Siting and Permitting, Construction, Operational	Planning, Siting and Permitting (cancelled)	Operational
Sustainability	XX	X	XX	—	XX	XX	X	X	—	X
Ecological Health	XX	XX	—	—	—	—	XX	—	X	X
Humans in Ecosystem	X	X	X	X	XX	X	XX	X	X	—
Complexity	—	X	—	—	—	X	X	—	—	—
Temporal	X	XX	XX	XX	X	XX	X	X	XX	XX
Spatial	XX	XX	XX	X	XX	XX	X	X	X	XX
Economics	—	—	—	—	—	—	—	XX	—	XX
Stakeholders	X	X	—	X	X	X	X	X	X	X
Science-based	X	XX	XX	X	X	XX	XX	X	XX	X
Technological	—	XX	XX	—	—	—	X	X	XX	X
Adaptive	XX	XX	X	XX	XX	X	XX	XX	X	XX

X = Implemented to some degree within project.

XX = Implemented within project.

5.0 Discussion

The RBM framework was adapted from EBM criteria as a means of examining, through a set of wind energy case studies, the range and application of studies, monitoring foci, and mitigation measures that are prevalent in wind farm development around the world. The intent is not to demonstrate that certain countries, or certain types of wind farms, are most closely aligned with the principles and implementation of RBM, but rather to examine how wind energy development may potentially use RBM to further the goal of ensuring that low-carbon wind energy development can proceed while protecting fragile local and regional environments.

5.1 Uncertainty in Assessing Wind Effects on Wildlife

Collection of data around wind farms is inherently difficult because, like all natural systems, there is extensive natural variability in the response of wildlife and habitats to change. In addition, relatively little is known about the mechanisms that govern the number of birds or bats that may collide with turbine blades, the effects that building roads may have on wildlife corridors, the effects that loud noises associated with offshore wind installation may have on marine mammal or fish populations, or a number of other effects. This lack of knowledge about cause-and-effect mechanisms for wind impacts on wildlife leads to inherent uncertainty, further complicating how monitoring programs can be focused for optimum knowledge capture.

5.2 Constraints to Implementing the Risk-Based Management Framework

The many constraints on wind farm development will make it difficult to meet some of the criteria for the RBM framework. For example, the need to collect additional baseline and monitoring data; ensure that monitoring continues year-round even in cold or inclement weather; hire stakeholder facilitators; and bring together a larger and more diverse scientific team that has expertise in aspects of wildlife, habitat, ecosystem processes, economic and other human uses, and ecological integrity. Each of these constraints will add to the cost of preparing for, constructing, and operating a wind farm. This could lead to increases in financial risk and strain the capabilities of emerging nations to expand wind power. To implement a RBM approach it will be necessary to determine who must bear these increased costs. Governments and regional authorities have a significant stake in ensuring that public resources, including native species and habitats, are protected, and in developing new low-carbon energy sources. Shared responsibilities and costs between the private developer and the public entities offer the best chance of success for protecting environmental assets and producing power (cf. Stabell and Steel 2018; May 2019).

The RBM framework was developed to embrace the values of the EBM process, and was then modified to reflect components and attributes pertinent to wind farms, based on the range of management directions that planning, developing, and operating wind farms have taken in countries around the world. Developing a framework that is usable for land-based and offshore wind cases is complicated by the high level of heterogeneity that exists between geographic locations, indigenous and migratory wildlife species, national laws and regulations, stakeholder interests, regional and intercontinental migratory corridors, and national/international financial incentives for development. The framework reflects these complications and, of necessity, tends toward generalizations in describing the desired outcomes of a RBM system.

5.3 Case Studies and the Risk-Based Management Framework

Examination of 10 case studies from eight countries, both land-based and offshore wind, allows for the comparison of how commonly the criteria adapted from EBM have been applied to a small but diverse set of wind energy projects. Looking at the six land-based wind projects and four offshore wind projects, one sees a diversity of management actions and strategies for environmental protection (Table 4-2), some of which correspond to criteria adapted from the EBM framework (Table 2-1). In particular, all the wind energy projects featured some degree of adaptive management including common themes of altering monitoring efforts or influencing mitigation measures in response to findings. Also of note is the consistent attention paid to ensuring that monitoring and other studies associated with wildlife (and occasionally habitats) consider spatial and temporal variability. Although there is some disparity in the focus of using science-based information to make management decisions, all the case studies relied to some degree on studies and findings from the literature. Similarly, almost all the wind projects involved stakeholders to some degree in the consenting/licensing process; a few also brought stakeholders together to help guide future operation and development. The RBM framework criteria that seem to be least commonly met are those that consider economics and those that focus on understanding the overall complexity and interconnectedness of the system. Factors such as the effects on ecosystem services, the overall ecological health of the system, and the use of technology to monitor the wind farms are used for some projects and not for others.

5.4 Recommendations for Environmental Risk-Based Management of Wind Energy Development

Based on the goals set for RBM of wind farms and an assessment of several wind farm development phases from the case studies, a set of recommendations is proposed to enhance and enable RBM for wind energy development. Inherent in these recommendations are actions that will address necessary and challenging aspects of RBM, as well as a system for evaluating the effectiveness of the application of RBM, as measured by positive outcomes for wind energy development and interactions with the ecosystem. For land-based and offshore wind energy development, the recommendations are directed at robust assessments prior to development for populations and habitats that have a reasonable likelihood of being affected by development and operation of a wind farm; a hypothesis-based program of post-installation monitoring for interactions and population health; and mitigation for potential deleterious effects. Each step in the process (baseline assessment, post-installation monitoring, and mitigation) should be evaluated periodically, using adaptive processes for change when needed. Specific recommendations derived from the case study analysis are highlighted here.

5.4.1 Complexity of Ecological Interactions

Arguably the greatest difference between the more common types of species-by-species wind farm management and ecological RBM is the need to consider the ecological interactions of populations, habitats, and ecosystem functions (cf. May et al. 2017). The RBM framework developed here considers these interactions using the criteria of sustainability, ecological health, ecosystem services, and complexity (

). Although many of the wind case studies considered aspects of the environment beyond species under special protection, there was little focus on understanding the complexity and interactivity of other animals, plants, and ecosystem processes that support those populations. Similarly, virtually no consideration was given to predator-prey interactions, or species competing for food or spatial resources. Temporal and spatial ranges that support wildlife of particular interest are also key to understanding and protecting ecological complexity (Burkhard et al. 2011). The wind case studies generally focused baseline and post-installation monitoring in the vicinity of the wind projects; however, species of concern may have larger home ranges, and migratory species can be affected by stressors at greater distances. Most of the case studies provided seasonal baseline and monitoring data for assessing populations of concern, but there is also a need to address longer-term cumulative effects that cover the life history of species. To understand the complexity of systems potentially affected by wind development it is important that these interactions be considered. Data collection and analysis, and the mitigation actions guided by them, must acknowledge and incorporate to the greatest degree possible, the complexities of spatial and temporal changes in populations and habitats, as well as ecological interactions between predators/prey and competitors.

5.4.2 Science-Based Data Collection

The underpinnings of environmental regulations and the need for data collection at each phase of wind farm development rely on scientific research that has evaluated potential causative linkages between wind farms and wildlife/habitats/ecosystem processes. For each wind case study, the documents describing data collection and analysis efforts reflect underlying scientific principles; however, many of the case studies suggest that monitoring programs are driven by regulatory requirements that are not necessarily underpinned by scientific questions. Each of the wind farm cases includes some degree of AM in its plan, which indicates a desire to examine and decrease scientific uncertainty. Based on the cases studies, there is room for improvement in applying scientific principles to the collection and analysis of data, beginning with the design of sampling plans, examination of appropriate sampling intervals to capture changes in life history and seasonal signals, trophic interactions, and effects of external factors such as weather patterns and changing climates. Particularly evident was the lack of studies to address questions related to the potential effects on ecosystem structure, function, and services. Where data are collected to describe the baseline of wildlife populations and habitat quantity/quality, as well as post-installation monitoring, they should be based on questions of scientific importance (such as population-level effects, changes in critical habitat for species under stress, etc.), provide adequate ancillary data that can be used to interpret findings, and to the greatest extent possible be implemented using the same collection methods for pre- and post-installation studies.

5.4.3 Mitigation Hierarchy

Mitigation measures for wind farms are commonly thought of as ways to decrease adverse effects, generally after construction or operation has begun (May 2017). Under RBM it is prudent to also consider design, siting, and operational plans as means of decreasing risk through avoidance. A key element of decreasing ecological risk for land-based wind is the micro-siting of turbines within a wind farm to ensure the least impact on key species and habitats. Each case study lays out a series of mitigation measures that can or will be instituted for the wind farm. The mitigation measures vary by the location and size of the wind project, species of concern, and whether the wind farm is land-based or offshore. Typically, mitigation measures among the land-based wind farms include measures to decrease the impacts of road building and other construction-related activities, as well as curtailment or other operational changes to decrease collision risk. A few cases include other operational measures, such as painting towers for increased wildlife visibility, as in the Smøla case study. Offshore wind farm mitigation is most attuned to decreasing the effects of construction, such as underwater noise and increased vessel traffic, and virtually no curtailment or other operational changes have been built in to date (Joos and Staffell 2018). In managing land-based and offshore wind farm case studies, monitoring results should be reevaluated and monitoring efforts realigned to act as mitigation measures, particularly in the pursuit of decreasing scientific uncertainty. It is the latter actions that most strongly support RBM for wind farms—using post-installation monitoring results to guide appropriate environmental mitigation measures during construction, operation, and decommissioning. In addition, the tenets of RBM guide mitigation measures (including monitoring efforts) to be proportionate to the risk to target wildlife populations, habitats, and ecosystems.

5.4.4 Integration of Adaptive Principles

All the case studies exhibited elements of AM principles for wind farm development. However, only a few specifically required the development and implementation of AM plans aimed at protecting populations at risk, and virtually none considered additional aspects of the ecosystem. Most notably missing from the application of AM were measurable feedback loops that would apply outcomes from mortality and population monitoring data to the broader ecosystem. In an ideal application, changes in populations from wind farm collisions or other likely effects would trigger increased monitoring of related species (predators, prey, competitors), linked habitats and migratory corridors, and (particularly at sea) ecosystem processes like circulation and sediment transport. However, the investment in understanding these linked processes could substantially add to monitoring costs and therefore financial risk to a wind project. Implementing full AM policies should be the purview of governments seeking to reduce scientific uncertainty and support future wind energy development over landscape or regional scales. Conversely, adaptive processes must also allow for decreases in monitoring and mitigation efforts if monitoring data indicate a lower than anticipated risk to species under special protection and the habitats that support them.

5.4.5 Inclusion of Stakeholders

Virtually every national, regional, and sub-national jurisdiction requires that stakeholders play a role in some aspect of consenting and licensing wind farms on land and at sea. The requirements may vary by location, but, as shown in the case studies, most public involvement focuses on the opportunity for stakeholders to provide input and comment on plans and procedures prior to authorities granting permission to site and construct a wind farm. A smaller number of the case studies represent a more integrated stakeholder approach throughout the life of the wind farm. Notably, the Jura mountains wind farms require a committee of stakeholders who meet to review monitoring data and help to set operating specifications for future periods. For several of the wind farm cases, the proponents exceeded the legally required stakeholder engagement, understanding that consulting with affected stakeholders and the general public early and often helps to reduce opposition to the development, and can often generate useful suggestions and good will. Under the RBM framework developed here, the engagement of stakeholders is necessary above and beyond what specific laws or regulations require. In addition to lowering opposition to projects, stakeholders who have engaged in one successful wind farm development can be key supporters of subsequent projects, and they can provide local knowledge, and under certain circumstances, community involvement in financing and offtake of power.

5.4.6 Focus on Social and Economic Outcomes

Ecological risk is unavoidably linked to social acceptance of wind farm development. Opposition and support for wind development often hinges on perceptions of risks or benefits that will accrue to local communities and regions (May 2019). Many of the concerns are associated with the proximity of stakeholder properties and activities to proposed wind farms, including visual effects. In general, stakeholders object less to offshore wind farms than those on land (Jones and Eiser 2010). It is very common for opposition to wind farms to be presented as a concern about environmental risk, even if underlying social and economic issues are at the base of the concern. Understanding the potential social and economic risks and benefits of a wind farm prior to consenting and licensing has the same effect as engaging with stakeholders about ecological concerns: it decreases the chances of large organized opposition to development and increases the potential positive outcomes of support and acceptance. Similarly, some degree of social and economic data is commonly required for consenting and licensing applications. Specific social and economic aspects of potential conflict may differ between land-based and offshore wind, but the reactions may be analogous. Examples include road building and encroachment on agricultural lands creating potential concerns on land, while proximity to shipping lanes and fishing grounds may concern those who make a living from the sea.

6.0 Conclusions and Best Practices

The examination of risk-based tools and management structures leads to the conclusion that management of land-based and offshore wind farms can be enhanced by deploying wind energy projects concurrent with risk identification and minimization. While ecological risk is the subject of this paper, a cascading set of risks are associated with or directly affected by ecological risk, most notably different aspects of financial and reputational risk (Appendix A).

Although there are arguably many different ways to view and evaluate risk (Appendix B provides a subset of these), the authors believe that EBM provides the most useful set of indicators related to wind farm development and operation. The EBM-influenced framework developed here was designed to deliver the most pertinent measures of how wind energy development might fit into a risk-based system. The wind farm case studies provide a snapshot of the range of land-based and offshore wind farms, covering most phases of development from planning and consenting through construction, operation, and repowering. These cases are likely not representative of all wind farms, nor are they intended to show all risk-based evaluations and management actions for any particular type of wind energy development. Additional cases could improve the picture of risk-based applications and provide further insight into how frameworks, such as the one developed here, could improve the management of individual wind farms and help regional and national authorities plan for larger landscape-scale development of wind on land and at sea.

The examination of case studies and the development of the RBM framework are first steps in operationalizing the application of risk-based wind energy development. More detail is needed to guide implementation of RBM from a general to a very specific scale. A series of best practices is offered here as a start; application of these best practices and the specifics of assessments, monitoring, and mitigation plans that decrease scientific uncertainty and provide large-scale protection to living resources must be tailored to each geographic region and each set of national goals for renewables development and environmental protection.

6.1 Best Practices

Based on the analyses of the case studies and the scientific literature, we suggest the following best practices for applying RBM to wind farms:

- During the initial wind farm planning stage, evaluate the proposed actions within a RBM framework. The framework developed here can serve as an example, although there are other approaches in the literature. Key steps should include:
  - Examine the criteria that support ecological integrity and manage risk to the environment, working with the stakeholders from the start.
  - Measure the criteria against proposed actions.
  - Pay further attention throughout the wind farm development process to determine whether those actions are unlikely to meet the needs of a healthy environment.
  - Empower the wind farm proponent, the regulators, and a range of stakeholders to collectively determine the definition of environmental health in the presence of wind farms.
- As part of evaluating the risk of a proposed wind farm, let the complexity of the ecological system in the vicinity of the project drive the data collection, modeling, and analysis efforts. In many cases, the more complex relationships (like predator-prey interactions and other ecosystem responses) may

be beyond the scope of a single wind farm and should be undertaken by national or regional governments to aid in planning for future wind energy expansion.

- Although regulatory requirements will always drive what is asked of wind farm developers, ensure that the data collection, analysis, and mitigation measures are science-driven. This will guarantee that resources spent on data and mitigation actions have solid scientific underpinnings, and that data generated by the wind farm will add to the understanding of wind/wildlife/habitat/ecosystem interactions. Adhering to science-based approaches will ensure that data and mitigation efforts will be proportionate to the risk to the ecological system, and the addition of these data to the public record will lead to a decrease in scientific uncertainty around these interactions.
- Incorporate adaptive management principles into an RBM process for wind farms to enable the wind farm operator, regulators, and other stakeholders to understand the effects of the wind farm, and to make mid-course corrections in data collection, analysis, and mitigation.
- Involve stakeholders at multiple stages in the life of a wind farm, including planning, siting, consenting processes, monitoring, and mitigation decisions. Doing so will be to the advantage of all parties; it will ensure that the least damage possible is done to the natural environment, while enabling the development of the low-carbon energy source. Inherent to engaging stakeholders is the need for the developer and the regulator to acknowledge that environmental issues are often tied up with social and economic risks and benefits, particularly in the eyes of the public and other stakeholders. These issues must be addressed along with the environmental issues.

7.0 References

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Appendix A – Risk Classifications for Wind Energy Development

The following table lists risk classifications for wind energy development (adapted from Gatzert and Kosub 2015). Many of these risks are related and interdependent. For example, ecological risk may contribute to reputational risk, and business and financial risk may be affected by ecological and reputational risk. Tradeoffs may be necessary to balance the multiple types of risk that may occur at a wind farm; for example, focusing on ecological risk may increase costs, or change construction methods, which could conceivably increase financial risk.

Risk Type	Description/Examples
Regulatory/policy	Regulatory/policy uncertainty, support for regulatory processes, and changes in perceptions of specific risks; policy (in)coherence, power structures, government office responsible for policy.
Strategic or business	Insufficient expertise, insufficient public understanding of the issues, insufficient public acceptance, complex approval process, insufficient management know-how, procedural risk (e.g., lack of clear guidelines and/or lines-of-command regarding responsibilities).
Liability/legal	Contract and sub-contract interface risk, liabilities to third parties, low cost bids.
Construction	General construction risks, grid availability and connection risks, weather/natural hazards risks, generic supply chain bottlenecks, design risks, quality risks, permitting risks.
Operations and maintenance	Risks to the operation and maintenance (O&M) of wind farms as a result of meeting satisfactory performance from permit requirements (e.g., impact of shutdown on demand on turbine warranty, on scheduled and unscheduled maintenance). These include general O&M risks, warranties and liquidated damages availability risks, weather/natural hazards risk of damage to wind turbines, and technological and innovation risks.
Security	Physical security risks, cybersecurity risks.
Reputational/social	Risks deriving from the loss of confidence in and the ability to succeed for a wind developer, investor, or operator due to the failure of a wind farm to reach operational status or to meet regulatory standards requiring mitigation, curtailment, or termination. Regulatory and management agencies may also suffer loss of reputation if they fail to reach satisfactory arrangements allowing the development of wind energy desired by the public. These arrangements include joint venture partners or supplier risk, brand damage, and workforce unrest. Environmental planning companies and practitioners may also face reputational risk from nature conservation organizations or those opposed to wind energy development.

Appendix B – Risk-Based Management Methods

The following table lists risk-based management methods applied to industries and natural resource management (adapted from Linkov et al. 2006).

RMB Method	Key Elements	Strengths	Limitations	Applications of Methods
01. Comparative risk analysis (CRA)	Used to compare relatively well-defined risks or to set priorities; also known as risk ranking or relative risk ranking (Konisky 2001)	Construction of a two-dimensional decision matrix that contains project alternatives' scores on various criteria (Linkov et al. 2006)	Lacks a structured method for combining performance and criteria to identify an optimal project alternative (Linkov et al. 2006)	CRA is a system of numerical scores used to quantify the merits of diverse options on a single scale. It has been applied to environmental protection (Duijm 2009), drinking water contamination (Williams et al. 2002), and energy supply systems (Ramanathan 2002).
02. Multiple-criteria decision-making (MCDM)/Multiple-criteria decision analysis (MCDA)	Used to evaluate and choose among alternatives based on multiple criteria using systematic analysis that overcomes the limitations of unstructured individual or group decision-making (Linkov et al. 2006)	Provides a systematic approach for integrating risk levels, uncertainty, and valuation; helps decision-makers evaluate and choose among alternatives based on multiple criteria using systematic analysis that overcomes the limitations of unstructured individual or group decision-making (Linkov et al. 2006)	Few MCDA approaches are specifically designed to incorporate multiple stakeholder perspectives or competing value systems (Linkov et al. 2006)	MCDM or MCDA evaluates multiple conflicting criteria in decision-making usually with the goal of identifying a preferred option or scenario. MCDM evaluates options based on a set of criteria such as resource availability, technical feasibility, ecological impact, financial viability, educational potential, and social as well as economic impacts (Nigim et al. 2004). It has been applied to health technology assessment (Thokala and Duenas 2012), sustainable development (Munda 2005), other regulatory decision-making (Linkov et al. 2006), and renewable energy (Lee et al. 2009; Hanssen et al. 2018).
03. Multi-attribute utility theory	Expression of overall performance of an alternative in a single, non-monetary number representing the utility of that alternative; criteria weights often are obtained by directly surveying stakeholders.	Easier to compare alternatives whose overall scores are expressed as single numbers; choice of an alternative can be transparent if highest scoring alternative is chosen; theoretically sound – based on utilitarian philosophy; many people prefer to express net utility in non-monetary terms.	Criteria weights obtained through less rigorous stakeholder surveys may not accurately reflect stakeholders' true preferences; rigorous stakeholder preference elicitations are expensive.	Multi-attribute utility theory allows for tradeoffs when multiple attributes affect a decision for which there is a level of uncertainty. This theory has been applied to land-use alternatives (Ananda and Herath 2005), emergency management (Kailiponi 2010), and manufacturing systems (Hasan et al. 2013).

RMB Method	Key Elements	Strengths	Limitations	Applications of Methods
04. Analytical hierarchy process (AHP)	Criteria weights and scores are based on pairwise comparisons of criteria and alternatives, respectively.	Surveying pairwise comparisons is easy to implement.	The weights obtained from pairwise comparison are strongly criticized for not reflecting people's true preferences; mathematical procedures can yield illogical results. For example, rankings developed using AHP are sometimes not transitive.	AHP is a structured technique for organizing and analyzing complex decisions and has been applied to urban stormwater systems (Shariat et al. 2019) and flood vulnerability (Radmehr and Araghinejad 2015).
05. Outranking	One option outranks another if "it outperforms the other on enough criteria of sufficient importance (as reflected by the sum of criteria weights)" and it "is not outperformed by the other in the sense of recording a significantly inferior performance on any one criterion" (Majumder 2015); and it allows options to be classified as "incomparable."	Does not require the reduction of all criteria to a single unit; explicit consideration of possibility that very poor performance on a single criterion may eliminate an alternative from consideration, even if that criterion's performance is compensated for by very good performance on other criteria.	The algorithms used in outranking are often relatively complex and not well understood by decision-makers.	Outranking compares among risk preferences, often with incomplete information (Wang et al. 2014), and has been applied to credit risk modeling (Doumpos and Figueira 2019), climate and energy policy (Neofytou et al. 2019), and marine spatial planning (Jajac et al. 2018).
06. Ordered weighted averaging (OWA)	OWA involves two vectors of weights: criterion importance weights and order weights. The reordering procedure is central to the OWA method. It involves associating an order weight with a particular ordered "position" of the weighted attribute values (Yager 1988; Rinner and Malczewski 2002).	Allows decision-makers to change the form of attribute (criterion) combinations, providing a sound basis for designing decision analysis tools that have the capacity to explore different decision rules (Rinner and Malczewski 2002).	The underlying assumption of the spatial homogeneity of the OWA parameters fails to adequately represent spatial variability (Liu 2013).	OWA averages criteria based on the level of risk and considers tradeoffs that are deemed acceptable. It has been applied when addressing needs for end-use suitability (Malczewski 2006; Drobne and Lisec 2009), conflict management (Mianabadi et al. 2014), socioeconomics (Liu 2013), and powerlines and wind energy (Hanssen et al. 2018).

RMB Method	Key Elements	Strengths	Limitations	Applications of Methods
07. Bow-tie analysis (BTA)	BTA is an integrated probabilistic technique that analyzes accident scenarios in terms of assessing the probability and pathways of occurrences (Duijm 2009); it is intended to prevent, control, and mitigate undesired events through development of a logical relationship between the causes and consequences of an undesired event (Dianous and Fiévez 2006).	BTA has not only proven to be valuable in mishap prediction, but has also demonstrated its importance in analyzing past accidents and signifying improvements to avoid further re-occurrence of undesired events (Bellamy et al. 2007); it is able to provide a suitable level of simplification of the causal factors in order to be able to summarize large quantities of data into a relatively small number of common scenarios, which can cover the majority of the accidents (Mokhtari et al. 2007).	The traditional "bow-tie" approach is not able to characterize model uncertainty that arises due to the assumption of independence among different risk events; required input data are often hard to come by and are subjected to a number of inherent uncertainties due to variant failure modes, design faults, poor understanding of failure mechanisms, as well as the vagueness of system phenomena (Shahriar et al. 2012).	BTA analyzes specific risks based on a diagram that links the causes of risk to a critical event, and generates the consequences of that critical event, in the shape of a bow tie (de Ruijter and Guldenmund 2016). BTA has been applied to oil and gas pipelines (Shahriar et al. 2012), seaports and offshore terminals (Mokhtari et al. 2007), medication safety risk (Wierenga et al. 2009), and ecological risk (Cormier et al. 2018a, 2018b, 2019).
08. Cumulative effects assessment (CEA)	CEA focuses on the receiving environment and considers all of the effects on a given receptor; when the scale of the CEA is properly inclusive, the ability to manage cumulative effects caused by many individually insignificant activities is enhanced. Including these "small" actions is essential for effective CEA (Therivel and Ross 2007).	Because of the broader scale at which such CEAs are carried out, a wider range of management measures will be possible at the strategic level (Therivel and Ross 2007).	Much of the cumulative effects science that shows how multiple stressors accumulate in the environment and the effects of multiple stressors are not translated into practical and accessible guidance that the community of professionals conducting CEA can use; most CEAs do not adequately capture potential cumulative effects; CEA practice varies by the geography, role, and experience of the practitioner – inconsistency in practice, especially with respect to establishing a baseline, selecting the spatial and temporal scales of analysis, and determining significance, was directly related to how practitioners initially defined impact in their CEA (Foley et al. 2017).	CEA aggregates risk from multiple stressors and has been applied to wetland restoration (Bedford 1999), ecological sustainability (Sutherland et al. 2016), wind energy (Goodale 2018; IFC 2017), and marine management (Stelzenmüller et al. 2018).

RMB Method	Key Elements	Strengths	Limitations	Applications of Methods
09. Layer of protection analysis (LOPA)	LOPA allows practitioners to understand the risks of their processes, the independent layers of protection that are in place, and where additional risk reduction is needed to achieve tolerable risk (Willey 2014; IEC/DIS 2017).	Incorporation of human performance through independent protection layers and human initiating events (Myers 2013); faster quantification of severe risk scenarios (Bridges and Clark 2009).	Limitations range from LOPA's design as an engineering analysis tool, its focus on single initiating event-consequence pairs, its simple approach and the balance between accuracy and science, and apparent limitations in use of LOPA rules, to a limited base of experts once studies go beyond basic LOPA – this is particularly true when addressing human factors and operating errors (Myers 2013); many times there is weak definition of the consequence that is being avoided, so an independent protection layer does not always match up well with the consequence (Bridges and Clark 2009).	LOPA provides a detailed, semi-quantitative assessment of the risks and layers of protection associated with hazard scenarios (Wiley 2014). It has been applied to chemical risk (Wei et al. 2008), liquefied natural gas (Yun et al. 2009), and pipeline safety (Markowski and Mannan 2009).
10. Ecosystem-based management (EBM)	Accounts for many aspects of ecological health, in addition to bringing human activities and benefits into the process.	Covers all critical aspects of ecological health and ecosystem services (Christensen et al. 1996; Ruckelshaus et al. 2008; Barnes and McFadden 2008).	Need for extensive data collection that may be beyond the capacity of small developments and other projects (Christensen et al. 1996; Ruckelshaus et al. 2008; Barnes and McFadden 2008).	EBM considers human as well as environmental/ecological factors, with approaches that embrace holistic methods to include humans in an integrated view of managing resources while sustaining ecological integrity (Christensen et al. 1996). It has been applied to managing marine resources and fisheries (Ruckelshaus et al. 2008; Barnes and McFadden 2008; Long et al. 2015).

Appendix C – Case Studies

The tables in this appendix contain more detail about each of the following cases studies first introduced in Table 4 2.

1. Crudine Ridge Wind Farm, New South Wales, Australia
2. Norther Offshore Wind Farm, Belgium
3. Smøla Wind Farm, Norway
4. Candeeiros Wind Farm, Portugal
5. Swiss Jura mountains, Switzerland
6. Moray Firth Offshore Wind Projects, UK
7. Sierra de los Caracoles Wind Farm, Uruguay
8. Block Island Offshore Wind Farm, United States
9. Cape Wind Energy Project, United States
10. Iowa Wind Energy Project Portfolio, United States

C.1 Crudine Ridge Wind Farm, New South Wales, Australia

Topic Area	Specifics	Description
Description of Project	Project Name	Crudine Ridge Wind Farm
	Location (country, region, land-based wind (LBW) or offshore wind (OSW), habitat type)	New South Wales, Australia (LBW)
	Size of project (no. turbines, MW, geographic extent)	Under construction: 37 turbines, 135 MW capacity https://www.crudineridgewindfarm.com.au/
Wind Energy Development Issues	Major ecological/environmental issues addressed	◆ Loss of threatened flora and fauna habitat ◆ Impacts on birds and bats from collision, disturbance, and barrier effects
	Lifecycle stage of project where issues were addressed	Pre-construction and construction
RBM-Related Management	Particular management strategies used to address issues	Ecological approach to management (not necessarily EBM) and adaptive management **Biodiversity Management Plan (BMP)** A BMP was developed as part of the overall Environmental Management Strategy. ◆ The BMP describes the following measures that will be implemented to manage and mitigate unavoidable impacts associated with the construction of the project: • Minimize the amount of clearing within the footprint as far as practicable. • Manage potential indirect impacts on threatened plant species, including the Small-Purple Pea (*Swainsona recta*). • Rehabilitate and revegetate temporary disturbance areas. • Protect vegetation and fauna habitat outside the approved disturbance area. • Maximize the salvage of resources within the approved disturbance area—including vegetative and soil resources—for beneficial reuse (including fauna habitat enhancement) on the site and/or in the biodiversity offset area. • Collect and propagate seed (where relevant). • Minimize impacts on tree hollows as far as practicable. • Minimize the impacts on fauna onsite, including undertaking pre-clearance surveys.

Topic Area	Specifics	Description
RBM-Related Management *continued*	Particular management strategies used to address issues *continued*	• Control weeds and feral pests. • Control erosion. • Control access. • Conduct bushfire management. ◆ Ongoing monitoring of environmental control measures will be undertaken to record the effectiveness of control measures and inform adaptive management of the environmental management plans and programs. ◆ Biodiversity Offset Strategy The biodiversity offset strategy determined that a "biodiversity offset area" of 674 hectares would be designated as "existing vegetation to be enhanced and protected." https://www.crudineridgewindfarm.com.au/wp-content/uploads/2018/01/CRWF_BiodiversityManagementPlan_Approved.pdf **Bird and Bat Adaptive Management Plan** ◆ Objectives are as follows: • Provide baseline data on bird and bat populations in the locality that could potentially be affected by the development, particularly "at risk" species and threatened species. • Implement a monitoring program capable of detecting any changes in the population of "at risk" birds and bats that can reasonably be attributed to the operation of the project, including pre- and post-construction (operational phase) presence. • Directly record impacts on birds and bats through a robust carcass search sampling protocol and prompt carcass removal. • Document an agreed-upon decision-making framework that outlines the specific actions to be taken and possible mitigation measures to be implemented to understand and reduce any impacts on bird and bat populations identified as a result of the monitoring, or in the event that an impact trigger is detected. • Detail specific monitoring for "at risk" bird and bat groups, such as the Wedge-tailed Eagle, and include monthly carcass searches, periodic species-specific surveys, and general bird utilization surveys.

Topic Area	Specifics	Description
RBM-Related Management *continued*	Particular management strategies used to address issues *continued*	• Minimize raptor activity in the area by controlling pests and minimizing the availability of raptor perches. • Use best practice methods for bat deterrence, including managing potential lighting impacts. • Detail specific and potential mitigation measures and related implementation strategies to mitigate any detected significant impacts on birds and bats. • Identify matters to be addressed in periodic reports about the outcomes of monitoring, the application of the decision-making framework, mitigation measures adopted, and their results. ◆ Management measures can be amended to ensure more effective management and mitigation are implemented in response to findings of monitoring. ◆ Conduct risk assessment following the procedure of AS/NZS ISO 31000 2009. • Use a process based on the Risk Evaluation Matrix Model used to measure the overall risk of a potential impact event (bird or bat striking blades or being deterred due to disturbance). • Conduct the assessment based on the likelihood of that event, and if it occurs, its consequences. https://www.crudineridgewindfarm.com.au/wp-content/uploads/2018/01/CRWF_BirdBatAdaptiveManagementPlan_Approved.pdf
	Tools used to address issues	Bird and Bat Risk Assessment – AS/NZS ISO 31000 2009, Risk Evaluation Matrix Model
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	The Environmental Management Strategy requires that a Risk Management Plan be prepared for construction of the project. The plan evaluates environmental risks and identifies mitigation measures and assigned roles and responsibilities of project participants. One of the key mitigation measures to be adopted in the plan will be to avoid and minimize vegetation clearance as far as practicable. Environmental objectives and targets will be set and reviewed regularly throughout construction, particularly for environmental risks where the adequacy of mitigations has been identified to be “Satisfactory” or less. Where necessary, Environmental Management Programs and Plans will be prepared to enable effective risk management, compliance with relevant statutory requirements, and consistency with the Environmental Policy, Environmental Management Strategy, environmental objectives and targets. https://www.crudineridgewindfarm.com.au/wp-content/uploads/2018/01/CRWF_BiodiversityManagementPlan_Approved.pdf

C.2 Norther Offshore Wind Farm, Belgium

Topic Area	Specifics	Description
Description of Project	Project Name	Norther Offshore Wind farm
	Location (country, region, LBW or OSW, habitat type)	Southern part of the North Sea (Belgian waters); this OSW project is located in an area of permanently submerged sandbanks (14–30 m depth).
	Size of project (no. turbines, MW, geographic extent)	44 turbines, in total 352 MW capacity, covers an area of approximately 38 km^2 (http://www.norther.be/#location)
Wind Energy Development Issues	Major ecological/environmental issues addressed	◆ Acoustic impacts on marine mammals from pile driving ◆ Impacts on seabird populations from risk of collision and displacement ◆ Impact on migrating birds from risk of collision ◆ Navigational and resultant environmental risk ◆ Cumulative impacts of the project with operational and other planned wind farms
	Lifecycle stage of project where issues were addressed	◆ Acoustics: installation ◆ Collision and displacement effects: operation ◆ Navigation: operation ◆ Cumulative impacts: assessment made for all life stages of the project (using worst-case assumptions)
RBM-Related Management	Particular management strategies used to address issues	◆ An adaptive management approach to monitoring and mitigation is being used for the environmental issues identified during the environmental impact assessment (EIA). ◆ Uncertainty and knowledge gaps are being addressed as part of an overarching long-term monitoring program funded by all nine offshore wind farms in Belgium. Studies can include all ecosystem components and their interlinkages with a focus on those issues identified during the EIA process. https://odnature.naturalsciences.be/mumm/en/windfarms/#monitoring
	Tools used to address issues	**Siting:** Collision risk (for navigation) assessment was part of the EIA and the layout of the wind farm was adapted to minimize navigational and resultant environmental risk. Obligatory collision-friendly foundation structures are minimizing the risk of oil spills.

Topic Area	Specifics	Description
	Tools used to address issues *continued*	**Mitigation of underwater sound:** A seasonal pile-driving ban limits the impact on marine mammals. During construction, active mitigation reduces the emission of high levels of impulsive sound during pile driving. The effectiveness of the mitigation methods are being evaluated. **Collision and displacement risk:** Pre-installation baseline monitoring, predictive modeling, and post-hoc monitoring (radar, sea-based counts, tagging data) are used to determine the need for additional measures.
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	Adaptive management allows for adjustment of mitigation measures based on monitoring results, which could result in either less or more stringent mitigation measures.

C.3 Smøla Wind Farm, Norway

Topic Area	Specifics	Description
Description of Project	Project Name	Smøla Wind Farm
	Location (country, region, LBW or OSW, habitat type)	Norway (LBW)
	Size of project (no. turbines, MW, geographic extent)	68 wind turbines, 150 MW capacity, 356 GWh production https://www.statkraft.com/energy-sources/Power-plants/Norway/Smola/
Wind Energy Development Issues	Major ecological/environmental issues addressed	The White-tailed Eagle, *Haliaeetus albicilla*, has been identified as the most vulnerable species because of increased disturbance and increased mortality from collisions with turbines.
	Lifecycle stage of project where issues were addressed	Operation
RBM-Related Management	Particular management strategies used to address issues	Adaptive management An impact assessment investigation for repowering the facility suggests mitigation measures resulted in increased visibility (e.g., painting turbines and turbine blades), deterrence (e.g., ultraviolet (UV) lighting), and operational minimization (e.g., selective shutdown). https://eolien-biodiversite.com/IMG/pdf/gartman-et-al-part_2-mitigation-measures.pdf Included in this adaptive management approach is the ability to adapt to the spatio-temporal conflict level in the repowered wind-power plant; i.e., where, when, and to what extent will there be conflicts between birds and turbines in the new wind-power plant. This allows for implementing mitigation measures at risky turbine locations and/or specific times of the year (e.g., contrast-painting rotor blades, operational adjustments, video-based warning systems). Research was carried out on the efficacy of updraft-based micro-siting of turbines (tested at another wind farm on the neighboring island of Hitra), painting blades and towers for better visibility, deterrence around turbines with UV lighting, and selective curtailment. Reference: Dahl, E.L., May, R., Nygård, T., Åström, J., and Diserud, O.H. (2015) “Repowering Smøla wind-power plant. An assessment of avian conflicts.” NINA Report 1135.

Topic Area	Specifics	Description
RBM-Related Management *continued*	Tools used to address issues	Innovative Mitigation Tools for Avian Conflicts with Wind Turbines (INTACT, www.nina.no/Forskning/Prosjekter/INTACT). The INTACT project tested the efficacy of contrast-painting one of three rotor blades to increase its visibility to birds, and contrast-painting tower bases to reduce tower collisions of ptarmigan. A geographic information system micro-siting tool was developed to delineate areas that feature thermal and orographic updrafts as well as leading lines in the landscape. https://tethys.pnnl.gov/sites/default/files/publications/WREN-AM-White-Paper-2016_0.pdf
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	An impact assessment investigation for repowering the facility suggests mitigation measures resulted in increased visibility (e.g., painting turbines and turbine blades), deterrence (e.g., UV lighting), and operational minimization (e.g., selective shutdown). Included in this adaptive management approach is the ability to adapt to the spatio-temporal conflict level in the repowered wind-power plant; i.e., where, when, and to what extent will there be conflicts between birds and turbines in the new wind-power plant. This allows for implementing mitigation measures at risky turbine locations and/or specific times of the year (e.g., contrast-painting rotor blades, operational adjustments, video-based warning systems).

C.4 Candeeiros Wind Farm, Portugal

Topic Area	Specifics	Description
Description of Project	Project Name	Candeeiros Wind Farm
	Location (country, region, LBW or OSW, habitat type)	Alcobaça / Rio Maior, Portugal (LBW in a National Park – Natural Park of Serras d'Aire e Candeeiros)
	Size of project (no. turbines, MW, geographic extent)	42 turbines, 121 MW, estimated annual production of 345 GW http://www.iberwind.pt/en/wind-farms/candeeiros/
Wind Energy Development Issues	Major ecological/environmental issues addressed	Impacts on bird (common kestrels, *Falco tinnunculus*) and bat populations from risk of collision risk https://tethys.pnnl.gov/sites/default/files/publications/pereira-et-al-2014.pdf https://www.springer.com/cda/content/document/cda_downloaddocument/9783319603506-c2.pdf?SGWID=0-0-45-1618448-p180902849
	Lifecycle stage of project where issues were addressed	Collision – operation
RBM-Related Management	Particular management strategies used to address issues	Adaptive management (informal) A 7-year post-construction monitoring program (2005–2012) revealed a high fatality rate of common kestrels and showed that birds frequently used the areas near the turbines for foraging, because these open areas are more suitable for searching for prey than the highly dense scrub typical of the vicinity. A mitigation plan involving habitat management was proposed and has been implemented since 2013; it aims to promote a shift in the areas used by kestrels for foraging by planting scrub species in the areas where the turbines are located and by implementing goat grazing to clear shrub areas in the areas far from the turbine locations. The mitigation program's objectives were to (1) decrease the level of attractiveness of the areas around the turbines and (2) increase food availability in areas outside the wind farm that have lower collision risk. Actions defined for implementation include (1) planting of native scrub species below the turbines to obtain denser vegetation in the area, making it less attractive to hunting kestrels; (2) opening patches inside the scrub areas to enhance habitat heterogeneity and therefore increase the density and availability in areas that have lower risk of collision; and (3) promoting extensive grazing by goats, also away from the turbines, to enhance habitat heterogeneity. These measures were also favorable to the red-bill chough population, because this species selects areas that feature short and sparse vegetation for feeding. http://docs.wind-watch.org/marques2014.pdf https://books.google.com/books/about/Biodiversity_and_Wind_Farms_in_Portugal.html?id=qaU2DwAAQBAJ&printsec=frontcover&source=kp_read_button#v=onepage&q=candeeiros&f=false http://cww2017.pt/images/Congresso/presentations/oral/CWW17_talk_S07_2_Santos%20et%20al.PDF

Topic Area	Specifics	Description
RBM-Related Management *continued*	Tools used to address issues	Monitoring and mitigation measures
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	After implementation of the monitoring program, in 2016 the kestrel mortality rate decreased, suggesting that negative impacts have been reduced, patched areas have been used, and the number of breeding pairs has increased from 7 to 10 pairs. Moving forward, kestrel monitoring will incorporate remote tracking of individuals using GPS data loggers to better understand daily activity. Mitigation measures for collision-risk minimization will also include reinforcing scrub planting with different scrub species, including rosemary (*Rosmarinus officinalis*) because it has a higher growth rate than kermes oak. http://cww2017.pt/images/Congresso/presentations/oral/CWW17_talk_S07_2_Santos%20et%20al.PDF

C.5 Swiss Jura Mountains, Switzerland

Topic Area	Specifics	Description
Description of Project	Project Name	None
	Location (country, region, LBW or OSW, habitat type)	Swiss Jura mountains (western part) (LBW)
	Size of project (no. turbines, MW, geographic extent)	13 distinct projects, 145 wind turbines in total over 2,000 km^2
Wind Energy Development Issues	Major ecological/environmental issues addressed	Impacts on bird and bat populations from risk of collision and displacement
	Lifecycle stage of project where issues were addressed	Collision and displacement effects – operation
RBM-Related Management	Particular management strategies used to address issues	There are four different stages of managing ecological risks: 1. Macro-siting must comply with a list of exclusion criteria defined in a cantonal directive. Among these criteria, known important sites for birds and bats preclude the development of wind energy. 2. Assessment of the cumulated impacts of all projects at the population level for selected bird and bat species, with and without mitigation measures of individual projects. 3. Definition of additional mitigation measures to reduce the residual cumulative impact. 4. Steering committee made up of key stakeholders to monitor the development of the projects and their wildlife impacts during operations.
	Tools used to address issues	**Stage 1** relies on GIS-based vulnerability mapping for breeding and migratory birds, as well as preliminary study for bats. • Breeding birds: classification of risk on a 4-level scale based on known nests or colony locations including a species-specific buffer for 11 species of national priority. • Migratory birds: classification of risk on a 3-level scale based on predictive modeling of songbird migration intensity and taking into account topography and wind distribution. • Bats: classification of risk on a 4-level scale depending on known roost sites, occurrence of endangered species, and expected bat activity in the vicinity of the project.

Topic Area	Specifics	Description
RBM-Related Management *continued*	Tools used to address issues *continued*	**Stage 2** relies on collision-risk modeling and population models. **Stage 3** relies on expert knowledge and negotiations, based on the results of stage 2. **Stage 4** monitoring results will be discussed and if the collision rate exceeds the predictions, stronger measures will be determined.
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	

C.6 Moray Firth Offshore Wind Projects, UK

Topic Area	Specifics	Description
Description of Project	Project Name	Moray Firth Offshore Wind Projects
	Location (country, region, LBW or OSW, habitat type)	East Coast of Scotland; these three OSW projects cover a combined spatial area of approximately 650 km^2, from 35–65 m depth.
	Size of project (no. turbines, MW, geographic extent)	There are three different projects: 1. Beatrice: 84 x 7 MW turbines giving 588 MW of installed capacity. Currently under construction with first electricity generation expected in 2018 and fully operational turbines in 2019. 2. Moray East: Consented in 2014, the construction of 950 MW installed capacity is scheduled to begin in 2019 or 2020. 3. Moray West: Under initial consultation with an Environmental Impact Statement scheduled to be submitted for public consultation.
Wind Energy Development Issues	Major ecological/environmental issues addressed	Acoustic impacts on marine mammals and fish from pile driving. Impacts on seabird populations from risk of collision and displacement
	Lifecycle stage of project where issues were addressed	Acoustics – installation Collision and displacement effects – operation
RBM-Related Management	Particular management strategies used to address issues	There are four different stages of managing ecological risks: 1. Initial zonal assessment identified the Moray Firth area for offshore wind farm development based on GIS mapping that included a large number of constraints (including information about seabirds and marine mammals). 2. Each project assesses worst-case scenario cumulative impacts at the population level for potentially affected marine mammal and seabird populations. 3. Mitigation measures are incorporated through the Environmental Impact Assessment process to reduce the risks; e.g., use of acoustic deterrent devices (ADDs) prior to pile driving to reduce likelihood of marine mammals being injured by acoustics, and use of fewer and larger turbines to decrease risks of collision and displacement effects on seabirds. 4. Regional Advisory Group (RAG), made up of key stakeholders, agree upon question-based monitoring that should be undertaken by the project developers. The results can inform future worst-case scenario cumulative effects assessment, making it less precautionary and more accurate.

Topic Area	Specifics	Description
RBM-Related Management *continued*	Tools used to address issues	There are bespoken tools for each of the four stages: **Stage 1** relies on GIS-based vulnerability mapping. The quality of the information contained in the tool relies upon broad-scale survey estimates for abundance and distribution of species and the accuracy of information that ranks sensitivity. **Stage 2** relies on predictive modeling of impact pathways to populations and the results are sensitive to the input parameters. The quality of information informing the input parameters can vary. **Stage 3** relies on results from Stage 2, and the efficacy of mitigation relies on additional information, whose quality can vary significantly. **Stage 4** requires that agreed-upon questions are addressed using specified sensors and data collection protocols in order to provide robust results.
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	

C.7 Sierra de los Caracoles Wind Farm, Uruguay

Topic Area	**Specifics**	**Description**
Description of Project	Project Name	Sierra de los Caracoles Wind Farm
	Location (country, region, LBW or OSW, habitat type)	Uruguay (LBW)
	Size of project (no. turbines, MW, geographic extent)	(1) Developed: 5 turbines, total of 10 MW capacity (2) Proposed on adjacent land: An additional 5 turbines, 10 MW capacity
Wind Energy Development Issues	Major ecological/environmental issues addressed	◆ Visual impacts ◆ Cultural resources ◆ Level of risk from the wind farm is not yet clear, but will be determined through systematic monitoring https://openknowledge.worldbank.org/bitstream/handle/10986/2388/662330PUBEPI00e0wind09780821389263.pdf?sequence=1.
	Lifecycle stage of project where issues were addressed	(1) Operation (2) Phasing, pre-construction
RBM-Related Management	Particular management strategies used to address issues	Phased development, adaptive management, landscape-scale management The Uruguay Wind Farm project involves only five turbines (10 MW), but another five turbines have been proposed as an adjacent, follow-up future development. In the meantime, planned monitoring will verify whether, as expected, the existing five-turbine wind farm can be operated without causing significant harm to birds or bats. In general, a phased approach—involving a relatively small pilot phase with intensive monitoring, followed by an expanded development phase—helps to prevent large-scale, essentially irreversible mistakes in wind-power site selection. **Preservation of Cultural Resources** The project developer paid special attention to how the installation of windmills on the highest point of an otherwise flat area—a ridge line of the Sierra de Caracoles mountain range—would be received by the largely affluent owners of cattle ranching estates and vacation homes in the vicinity. Instead of approving the original design, which would have erected 12 relatively short towers (each with an 800 kW generation capacity) on the ridge, the developer adopted a modified design consisting of five taller towers each with a 2 MW generation capacity. The new configuration occupied less space along the ridge and, despite the added height, was perceived to have a smaller aggregate visual impact. It had the added benefit of reducing the project's impact on the most prominent example of cultural patrimony in the area, an old stone wall spanning the ridge top that was built in the seventeenth century as a dividing line between estates.

Topic Area	Specifics	Description
RBM-Related Management *continued*	Particular management strategies used to address issues *continued*	**Mitigation or Enhancement Measures Taken or Proposed** Even though the wind farm site is presumed not to be of high risk (at least for birds), such monitoring is nonetheless needed to (1) verify whether or not a significant problem exists, particularly in the case of bats; (2) enable the potential adaptive management of wind farm operation to minimize bat or bird mortality; (3) predict the likely impacts of scaling up wind-power development, particularly the proposed future expansion at the Sierra de Caracoles of another 10 MW, but also in other areas of Uruguay with similar physical and vegetation characteristics; and (4) advance scientific knowledge worldwide in a field that presently faces a steep learning curve and would surely benefit from the Uruguayan data. **Bird and Bat Monitoring Plan** Agreed upon by the utility UTE and the World Bank, the Plan provides for (1) operating the turbines at the standard cut-in speed of 4.0 m/s during Year 1; (2) experimenting with 6.0 m/s (1/2 hour before sunset until sunrise) during Year 2, if the Year 1 monitoring finds (with correction factors) more than 5 dead bats/MW/year; and (3) if bat fatalities drop significantly during Year 2, then continuing with 6.0 m/s during Year 3. https://openknowledge.worldbank.org/bitstream/handle/10986/2388/662330PUBEPI00e0wind09780821389263.pdf?sequence=1.
	Tools used to address issues	None.
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	During a 2009 field visit, the World Bank team found that the nacelle (gondola) for Turbine No. 5 had two round holes where the caps were missing (the other four turbines had all their caps). These holes can attract birds (such as the locally common American Kestrel [*Falco sparverius*]) to roost or attempt nesting within the nacelles, which is hazardous to the birds because of the close proximity to the rotors. One of the proposed mitigation measures based on these observations is to ensure the nacelle holes are not missing caps. The rather extensive bare earth around the turbines poses low or moderate erosion risks, also implying a larger-than-needed ecological footprint for the project. Therefore, another proposed mitigation measure is to revegetate the cleared land. https://openknowledge.worldbank.org/bitstream/handle/10986/2388/662330PUBEPI00e0wind09780821389263.pdf?sequence=1.

C.8 Block Island Offshore Wind Farm, United States

Topic Area	**Specifics**	**Description**
Description of Project	Project Name	Block Island Windfarm
	Location (country, region, LBW or OSW, habitat type)	Northeastern U.S. (Rhode Island), 3 miles offshore, 30 m depth, soft bottom and shale. First farm in the U.S.
	Size of project (no. turbines, MW, geographic extent)	5 X 6 MW turbines. 30 MW
Wind Energy Development Issues	Major ecological/environmental issues addressed	◆ Acoustic impacts on marine mammals and fish from pile driving ◆ Benthic effects from installation and operation ◆ EMF of cables
	Lifecycle stage of project where issues were addressed	◆ Acoustics and additional vessel traffic: installation ◆ Benthic effects, EMF from cables: operation ◆ Bird and bat collisions: operation
RBM-Related Management	Particular management strategies used to address issues	Risk envelopes for pile driving http://dwwind.com/wp-content/uploads/2014/08/Environmental-Report.pdf ◆ Significant research projects carried out around the installation and early operation of the wind farm to inform later applications. ◆ North Atlantic Right Whales (NARWs) were of the greatest concern because they are highly endangered, their numbers are unknown, and mother-calf pairs are non-vocal and migrate along the coast to calving grounds in southeastern U.S. Additional vessel traffic from installation of particular concern for collision. ◆ Pile driving is also of concern for NARWs and other marine mammals.
	Tools used to address issues	◆ During construction: Marine mammal observers to trigger shutdown, research, and monitoring around installation. Studies to measure real-time sound. http://dwwind.com/wp-content/uploads/2014/08/Environmental-Report-Section-4.pdf ◆ During construction: Seasonal timing was used for construction when NARWs were least likely to be in the area. • During operation: research studies using underwater vehicles to observe habitat effects, measure EMF from cables • Pre-installation bird and bat studies showed that there were likely to be small effects. Post-installation monitoring for species of concern.

C.9 Cape Wind Energy Project, United States

Topic Area	Specifics	Description
Description of Project	Project Name	Cape Wind Energy Project
	Location (country, region, LBW or OSW, habitat type)	United States, Nantucket Sound (OSW)
	Size of project (no. turbines, MW, geographic extent)	Proposed: 130 turbines, 468 MW capacity
Wind Energy Development Issues	Major ecological/environmental issues addressed	“Moderate” impacts on migratory birds (as per FEIS)
	Lifecycle stage of project where issues were addressed	Pre-construction
RBM-Related Management	Particular management strategies used to address issues	Adaptive management approach to monitoring and mitigation for non-ESA migratory birds ◆ Record of Decision (ROD) identifies the need to employ and further define best management practices (BMPs) • ROD expressly adopted and incorporated these BMPs into the lease. • ROD states that the lessee must evaluate avian use of the project area and design the project to minimize or mitigate the potential for bird strikes and habitat loss. ◆ The intention is to deploy technology and methods for assessing impacts of the proposed action and then using monitoring results to drive changes in mitigation requirements and readjustments to monitoring as needed ◆ Monitoring results • Monitoring results will determine the extent and scope of the adaptive management regime. • Monitoring results would not only provide an adequate evaluation of the effects of the project on the Migratory Bird Treaty Act and ESA-listed birds, but also help the agencies determine how well and how reliably the different monitoring techniques are functioning and/or how well they are being implemented. • Agencies agreed to obtain monitoring data, designed to reflect the actual impacts on migratory species, before establishing triggers or thresholds that will invoke mandatory adaptive management mitigation measures above those required in the lease.

Topic Area	**Specifics**	**Description**
RBM-Related Management *continued*	Particular management strategies used to address issues *continued*	◆ Avian and Bat Mitigation and Monitoring Plan (ABMP) • Program objectives have been refined since they were originally proposed. • The Plan includes study objectives and research questions that will be addressed through the pre-construction, construction, and post-construction periods. • The Plan may be further refined with input and assistance from regulatory agencies prior to its implementation in the field. • The Plan is intended to have the flexibility to be adjusted as needed based on new information, results of the field programs, and/or technical feasibility of program implementation. • Monitoring technique may be modified or reconsidered based on technical feasibility during implementation. https://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/Studies/EA_FONNSI_4_2011.pdf https://www.boem.gov/Cape-Wind-FEIS/
Other Important Information	Tools used to address issues	Mitigation measures and monitoring techniques/methods are informed by adaptive management methods
	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	In December 2017, Cape Wind Associates LLC relinquished its lease.

C.10 Iowa Wind Energy Project Portfolio, United States

Topic Area	Specifics	Description
Description of Project	Project Name	Iowa Wind Energy Project Portfolio
	Location (country, region, LBW or OSW, habitat type)	Iowa State, U.S. (LBW)
	Size of project (no. turbines, MW, geographic extent)	22 wind energy facilities operated by MidAmerican Energy Company across the state of Iowa, totaling 2,020 turbines and more than 4,040 MW in capacity
Wind Energy Development Issues	Major ecological/environmental issues addressed	Impacts on bats and bald eagles
	Lifecycle stage of project where issues were addressed	Operation
RBM-Related Management	Particular management strategies used to address issues	Ecological approach to management (not official EBM), adaptive management Development of a Habitat Conservation Plan (HCP) for the project portfolio ◆ Assess the impacts of the Projects on the Covered Species (several species of bats and the bald eagle). ◆ Provide mechanisms to avoid, minimize, and mitigate to the maximum extent practicable the impacts of the taking of the Covered Species. ◆ Ensure that incidental take from the projects will not appreciably reduce the likelihood that the Covered Species will survive and recover in the wild. ◆ HCP will also support conservation of other non-listed bat species through the proposed conservation measures that will minimize potential mortality and protect habitat suitable for all bat species. ◆ HCP describes the monitoring that will be used to confirm compliance with the incidental take permit (ITP). ◆ HCP also identifies funding assurances to ensure implementation of monitoring, mitigation, and any Changed Circumstances. This HCP includes all elements necessary to meet the criteria for ITP issuance. ◆ Includes Conservation Program: • Focuses on avoiding and minimizing potential impacts on Covered Species on Covered Lands and on compensating for the impacts of the taking of Covered Species through implementation of habitat restoration or protection measures in the State, which contains the populations determined by MidAmerican to be most likely impacted by the Covered Activities.

Topic Area	**Specifics**	**Description**
RBM-Related Management *continued*	Particular management strategies used to address issues *continued*	• Monitoring will be used to verify the effectiveness of these measures in meeting the biological goals and objectives of this HCP, provide information necessary to assess ITP compliance, and determine if adaptive management actions may be necessary to maintain permit compliance. • Biological goals ◦ Contribute to the long-term persistence of the Covered Species by developing mitigation projects that will support the survival and recovery of the Covered Species in Iowa. ◦ Contribute to maintaining the integrity of the populations of the Covered Species in Iowa by minimizing mortality of the Covered Species in the Permit Area. ◦ Increase our scientific understanding of the risk of wind-power development to the Covered Species in Iowa. ◆ Adaptive management • Ensure that take levels do not exceed the limits predicted in the HCP and authorized in the ITP. • The adaptive management framework is designed to trigger additional minimization or mitigation if cumulative annual take is on pace to exceed the ITP limits or to ensure that the impacts of the take have been fully offset. • An appropriate adaptive management framework also allows for reduced minimization following adaptive management changes if the annual take is predicted to be less than the ITP limits, indicating that reduced minimization back to baseline measures (blade feathering below the normal turbine cut-in wind speed) would maintain take below the ITP limits. https://www.fws.gov/midwest/endangered/permits/hcp/pdf/MidAmericanDraftHCP.PDF
	Tools used to address issues	None
Other Important Information	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions.	To address state-wide environmental impacts on bats and bald eagles, a HCP was developed for the Iowa Wind Energy Project Portfolio. The HCP assesses the impacts on the Covered Species (several species of bats and the bald eagle); provides mechanisms to avoid, minimize, and mitigate to the maximum extent practicable the impacts of the taking of the Covered Species; and ensures that incidental take will not appreciably reduce the likelihood that the Covered Species will survive and recover in the wild. The HCP also supports conservation of other non-listed bat species through the proposed conservation measures that will minimize potential mortality and protect habitat suitable for all bat species.

Topic Area	**Specifics**	**Description**
Other Important Information *continued*	Any aspects of the project not already covered that are pertinent to RBM; for example, specific monitoring results that resulted in changes in risk profile and mitigation actions. *continued*	The HCP includes a Conservation Program that focuses on avoiding and minimizing potential impacts on Covered Species on Covered Lands and compensating for impacts of the taking of Covered Species through implementation of habitat restoration or protection measures, which contains the populations determined to be most likely impacted by the Covered Activities. The Conservation Program also sets biological goals to (1) contribute to the long-term persistence of the Covered Species by developing mitigation projects that will support the survival and recovery of the Covered Species in Iowa; (2) contribute to maintaining the integrity of the populations of the Covered Species in Iowa by minimizing mortality of the Covered Species in the Permit Area; and (3) increase scientific understanding of the risk of wind-power development to the Covered Species in Iowa. Adaptive management approaches are also included to ensure that take levels do not exceed the limits predicted in the HCP and authorized in the ITP. The adaptive management framework is designed to trigger additional minimization or mitigation if cumulative annual take is on pace to exceed the ITP limits or to ensure that the impacts of the take have been fully offset.