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Masden, Elizabeth; McCluskie, Aly; Owen, Ellie ; Lagston, Rowena

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Renewable energy developments in an uncertain world: the case of offshore wind and birds in the UK

Elizabeth A. Masden[1]*, Aly McCluskie[2], Ellie Owen[3] and Rowena H. W. Langston[4]

1 Environmental Research Institute, North Highland College – UHI, University of the Highlands and Islands, Ormlie Road, Thurso, KW14 7EE, UK

2 The Royal Society for the Protection of Birds, Scottish Headquarters, 2 Lochside View, Edinburgh Park, Edinburgh EH12 9DH, UK

3 The Royal Society for the Protection of Birds, North Scotland Regional Office, Etive House, Beechwood Park, Inverness, IV2 3BW, UK

4 The Royal Society for the Protection of Birds, UK Headquarters, The Lodge, Sandy, Bedfordshire, SG19 2DL, UK

* Corresponding author. Email: elizabeth.masden@uhi.ac.uk.

Abstract: As marine renewable energy applications are increasing in the UK, environmental and cumulative impacts and their assessments are receiving more attention. The uncertainty, particularly surrounding cumulative impacts, however remains high and is becoming a cause of delay in the consenting process. This study examines the sources of uncertainty in environmental impact assessments and provides recommendations as to how these may be reduced, using the example of birds and wind farms. In the assessment of environmental impacts, uncertainty not only enters through the availability of empirical data but also data collection and analysis methods, linguistics and policy frameworks. Identifying and quantifying sources of uncertainty in environmental and cumulative impact assessments is critical to facilitating the development of an environmentally sustainable offshore wind industry.

Keywords: EIA; cumulative impacts; environment; risk; marine

1 Introduction

As governments pledge to invest in reducing carbon emissions, they are increasingly focussing on renewable-energy solutions, to reduce reliance on fossil fuels, though the environmental effects of such developments remain highly uncertain. Growing numbers of proposed marine renewable energy developments within strategic development zones create increasing pressures on the environment, making cumulative impacts, i.e. the environmental impacts from multiple projects or activities, a timely issue. Such has been the case in the UK, where concerns have been raised over the negative impacts of wind farms on birds [1], and where the scale of development now represents an unprecedented industrialisation of the marine environment.

Within the UK, the legal framework for the assessment of environmental and cumulative effects related to marine renewable energy refers to the EIA Directive (85/337/EEC), through The Marine Works (Environmental Impact Assessment) Regulations 2007, as well as ornithological impacts being considered in relation to the Birds Directive (2009/147/EC) and the Habitats Directive (92/43/EEC). In recent years the quality of assessments of ornithological impacts of renewable energy developments in the UK has been improving, with cumulative impacts now routinely considered. Variation remains however, in the quality and quantity of information provided and uncertainty still surrounds cumulative impacts and their inclusion in environmental impact assessment (EIA). There is also little recognition of the inherent uncertainty within the EIA process (including cumulative impact assessment; CIA) despite the fact that "…the knowledge base available for decision-making on environmental risks…is characterized by imperfect understanding of the complex systems involved" [2]. The aim of this paper is to highlight uncertainty within environmental and cumulative impact assessments, so to streamline the assessment and application process for marine renewable energy developments, whilst adequately assessing the potential impact of developments on marine wildlife. Sources of uncertainty are discussed and recommendations provided for methods of presenting and reducing uncertainty in environmental assessments. We focus on uncertainty relating to birds and offshore wind farms in the UK, but the principles are broadly transferable.

2 Types of uncertainty

"There are almost as many definitions of uncertainty as there are treatments of the subject" [3]. In this article we define uncertainty as a lack of knowledge, or "incomplete information about a particular subject" [4]. In order to manage uncertainty, it must first be identified and categorised and it is useful to consider a hierarchical framework when determining where uncertainty enters the environmental assessment process.

[Insert Figure 1 near here]

2.1 Level 1: Random and systematic uncertainty

Uncertainty can be categorised as random or systematic. Random (or aleatory) uncertainty is the natural variability related to the randomness or stochasticity of ecological systems. Systematic (or epistemic) uncertainty is therefore the non-random portion of uncertainty and is a function of human understanding and measurement of a situation or environment; for example, our perception of how a bird may be affected by a wind turbine and the subsequent measurement and collection of data. Increasing amounts of data can often reduce systematic uncertainty but this is not the case for random uncertainty particularly if the environment is inherently variable, though the natural variability can be characterised if measured [5].

2.2 Level 2: Linguistic, decision-making and knowledge uncertainty

2.2.1 Linguistic uncertainty

Linguistic uncertainty (or ambiguity) arises because language is vague and/or the precise meaning of words changes over time or between disciplines [5]. For example, cumulative impacts have previously been defined as "Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project" [6], with much ambiguity in phrases such as "reasonably foreseeable".

2.2.2 Decision-making uncertainty

Decision-making uncertainty relates to how knowledge and predictions are interpreted, communicated and used in the management and policy arena. It includes uncertainty in the priorities of decision-makers, e.g. government policies regarding renewable energy, as well as uncertainty in the regulatory process and surrounding the values of society. Decision-making uncertainty can be closely linked to linguistic uncertainty. For example, "When high uncertainty is not properly explained or understood, it can delay action or cause the selection of an inappropriate management decision" [5]. This is increasingly becoming a problem for wind farm applications where uncertainty surrounding cumulative impacts leads to a delay in the application process. Uncertainty also enters the decision making process in relation to CIA because data may not always be available for all proposed developments at the same time; this is therefore linked to knowledge uncertainty. Furthermore, this uncertainty increases where the application of legislation is unclear. For example, governments have a legal responsibility to maintain the integrity of the Natura network of protected sites, under Directive 79/409/EEC, as amended. However, in the context of already declining populations of seabird species, it is often unclear how legislation should be applied in consenting decisions for wind farm developments.

2.2.3 Knowledge uncertainty

Knowledge uncertainty refers to the limitation of our knowledge and understanding of a system. It may be caused by a lack of data, particularly because ecological data can be difficult to collect. Knowledge uncertainty is of particular importance when considering cumulative impacts because multiple projects will be involved such as the wind farms in the Firths of Forth and Tay in Scotland, each with associated knowledge uncertainty, thus knowledge uncertainty likely increases with increasing numbers of projects in a cumulative impact assessment.

2.3 Level 3

It is thought that birds are affected via four main pathways regarding offshore wind farms: habitat loss, collision mortality, barrier effects, and disturbance [7,8]. It is possible however, that our scientific understanding of the interactions of birds and wind farms is incomplete and the four main processes described above may not encapsulate all of the processes by which wind farms may affect birds. Knowledge is constantly changing and theories are challenged.

2.4 Level 4

Within each of the four main processes in Level 3 there may be uncertainty surrounding not only the theoretical understanding of the problem but also data collection and analysis. This can affect both our understanding of the probability of occurrence of an event and the severity of the event. For example, birds are known to collide fatally with wind turbines but the issue is one of frequency of interaction, persistence, conservation status, resilience of populations and how collisions may be minimised, all of which require understanding of the mechanisms leading to a collision. These mechanisms include the ecological attributes of species that may make them more or less likely to collide, but can be difficult to quantify [9].

Collision mortality uncertainty can be sub-divided into the uncertainty associated with: i) the understanding of the collision process i.e. the interaction between the bird and the wind turbine(s), ii) data and parameters, iii) model structure e.g. choice and structure of collision risk models and iv) model output. Further, for data and parameters, there may be uncertainty in data collection methods (for example, survey design), or in parameter estimation.

3 Reducing uncertainty in environmental assessments

3.1 Linguistic uncertainty

The first step to reduce overall uncertainty in environmental assessments is to reduce linguistic uncertainty and develop a standardised vocabulary. Reduced linguistic uncertainty will ensure that the expectations of those involved in assessments are aligned at an early stage of a project. Careful and consistent use of terms in documents across the renewable energy sector will help to reduce some of this uncertainty with a necessary addition being a glossary of terms to ensure there is no ambiguity in definitions. Establishing standard guidance documents and case study examples will also help to achieve reduced linguistic uncertainty [7,10–12].

3.2 Decision-making uncertainty

To minimise decision-making uncertainty, results from environmental assessments must be conveyed adequately to decision-makers to be useful in the policy arena. Keeping results and findings clear and simple where possible is important. There is a balance to be achieved between i) presenting a simplified account of a more complex situation which may be persuasive though pay insufficient attention to the reliability of the results and ii) emphasising the uncertainties in the results which may make them less accessible and less usable for policy-makers [4]. For example, when estimating the potential impacts of wind farms on birds, a deterministic model of collision mortality [13] may sometimes suffice, but not always; therefore the importance of uncertainty must be assessed in terms of the decision-making process.

3.3 Knowledge Uncertainty

Uncertainty is inherent in scientific research and need not be detrimental. It may not always be possible or necessary to minimise knowledge uncertainty and often we simply need to know enough and know how to best use the available information to inform a decision. This dictates however, that the uncertainty should always be described either quantitatively where possible or qualitatively, to provide a measure of confidence in the data which underpin decisions.

Current environmental assessments often lack measures of uncertainty around impacts that have been measured. It is not always possible to provide a quantitative measure of uncertainty, but a qualitative measure should be given. Equally, if an estimate for a parameter is cited, a measure of uncertainty should be given with this estimate [14]. The Intergovernmental Panel on Climate Change (IPCC) provide a system which comprises seven descriptors [15]. The uncertainty associated with underlying theories should also be assessed. For example, is the understanding of a system well-established and agreed upon [16]? The IPCC also suggest a verbal scale to express confidence in the theoretical understanding of a system using qualifiers such as ‘low’, ‘medium’ and ‘high’ [15]. This scale was recently used by Thompson et al. [17] to summarise their confidence in the data available in their study and should be used in all CIAs to present knowledge uncertainty.

There are well-established quantitative methods for calculating and expressing uncertainty, such as confidence limits which may be estimated directly or by techniques such as bootstrapping [4,16]. These metrics present a measure of confidence in the data which is unambiguous. It is often necessary to also consider the potential effect of any uncertainty. This is possible using sensitivity analyses and can show potential variation in key results should information or data in the study be incorrect. Sensitivity analyses were used to assess the effects of data uncertainty in a population viability analysis of the north Norfolk Sandwich tern population related to wind farm developments [18]. Not only do sensitivity analyses provide information on the implications of uncertainty but they can help to direct future studies or data collection [17] and therefore should be carried out wherever possible.

4 Conclusions

With increasing numbers of renewable energy developments, environmental and cumulative impact assessment is becoming ever more important. This paper has focussed on uncertainty within environmental assessments, which is one aspect which needs attention. There is much uncertainty surrounding the environmental impacts of the renewable energy sector and this uncertainty is not only associated with knowledge and data but also more strategically within language and decision-making processes. The task of assessing the environmental impacts of multiple developments will likely be a challenge for many years to come, but current methods should address and highlight uncertainties in the assessment process. In doing so, the challenges ahead may become more tractable and it may then be possible to cope with those uncertainties that are irreducible. In the case presented, more certain assessments of developments can be made to the benefit of sustainable offshore renewable industry and internationally important populations of seabirds [19].

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Figures

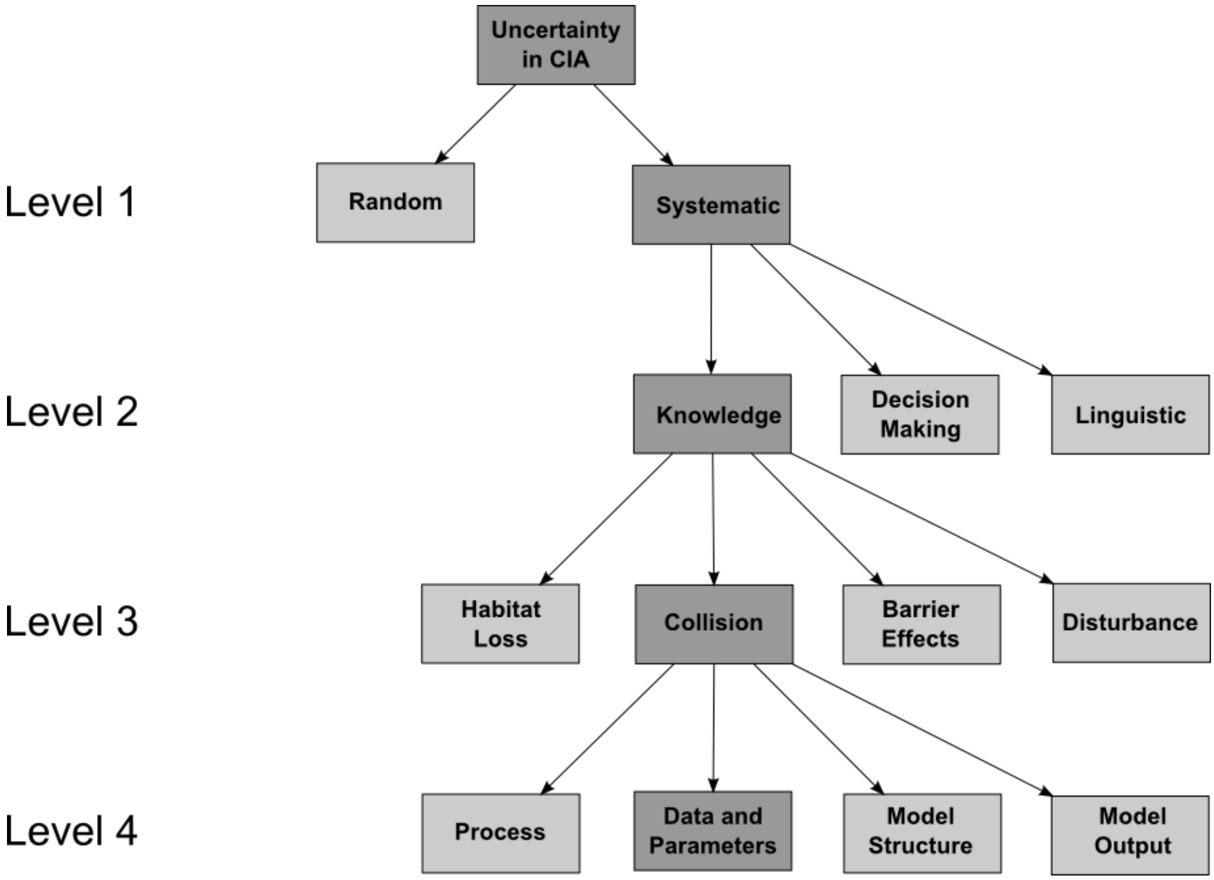

Figure 1: Hierarchical description of uncertainty within wind farm cumulative impact assessments. Dark grey boxes depict uncertainty in data and model parameters, on which collision risk estimation depends.