Can Risk-Based Approaches benefit future Offshore Renewable Energy deployment, planning and consenting processes?

Emma Verling, Iratxe Menchaca, Inês Machado, Thomas Soulard, Anne Marie O'Hagan

Abstract— The need to harness the vast energy resources of the oceans has led to a significant increase in the design, testing and deployment of novel technologies for Marine Renewable Energy (ORE). However, growth in this area has been slowed in part by several non-technological challenges, among them the ability to gain permissions to test and deploy installations. These consenting processes are often characterised by long bureaucratic procedures (with many authorities involved) and excessive environmental impact assessment studies, resulting in delays and additional costs to developers.

One option which may help to release this block is to adopt a Risk-Based Approach (RBA) to energy consenting, whereby an assessment of risk is used in the decision-making process. The EU-funded SafeWAVE project (www.safewave-project.eu) has focussed on this possibility in France and Ireland, building on the work of an earlier EU-funded project, WESE (https://www.researchgate.net/project/Wave-Energy-in-the-Southern-Europe-WESE), in which similar work was undertaken in Spain and Portugal. Here we present some of the findings from these projects, in particular the process to work towards a set of guidance for the use of RBAs in ORE consenting processes.

RBAs have already been used in the context of Maritime Spatial Planning and Ecosystem-Based Management and have been found to be useful for interpretation of data from experts, indicators and ecosystem models (Gimpel et al., 2013; Ma et al, 2023). Indeed, a number of RBAs have also been developed that are appropriate for Offshore Renewable Energy (ORE) consenting processes. A thorough review was undertaken of several recognised RBAs and common components were identified across five of the most useful and relevant of these. From these common components, a 'stepwise process' was formulated, specifically designed to be embedded into ORE consenting systems. This stepwise process (see Figure 1) has been constructed such that it can be presented to regulatory stakeholders in France and Ireland with a view to determining the feasibility of its implementation. Ultimately the outcome of these discussions will form the basis for the development of a guidance document on risk-based, adaptive management consenting processes with recommendations on how the process can be taken forward and utilised by regulators, planners and developers. While the development of a prescriptive procedure is not feasible (due to the varying nature of the ORE installations devices themselves as well as differing environmental conditions and impacts where devices are deployed), there is scope for providing guidance to assist regulators in taking a robust and holistic risk-based approach. Such a set of guidelines could facilitate a broader understanding and thus the wider use of RBAs, which in turn has the potential to remove one significant barrier to progress in the field.

***Keywords*— Consenting processes, Risk Assessment, Risk-Based Approach, Offshore Renewable Energy,**

I. Introduction

THE development of a Offshore Renewable Energy (ORE) sector is increasingly becoming one of the key low-carbon energy solutions for coastal nations in their drive both to tackle the impacts of a changing climate and to provide energy security in the face of this global challenge (Martinez et al., 2021). While harnessing the vast energy resources of the oceans has led to significant growth in the design, testing and deployment of novel

This work was part of the SafeWAVE project, co-funded by the by the European Climate, Infrastructure and Environment Executive Agency (CINEA).

E. Verling and AM O'Hagan are at MaREI: the SFI Research Centre for Energy, Climate and Marine, Environmental Research Institute, University College Cork, Ireland (email: emma.verling@ucc.ie and a.ohagan@ucc.ie).

I. Menchaca and J. Bald are at AZTI, Herrera Kaia, Portualdea z/g, 20110 Pasaia (Gipuzkoa), Spain (email. imenchaca@azti.es; jbald@azti.es)

I. Machado is at WaveEc Edifício Diogo Cão, Doca de Alcântara Norte, 1350-352 Lisbon, Portugal (email: ines.machado@wavec.org).

T. Soulard is at SEM-REV, 1 Rue de la Noe, 44321 Nantes Cedex 3, France (email: thomas.soulard@ec-nantes.fr).

Digital Object Identifier: https://doi.org/10.36688/ewtec-2023-306

technologies, progress in this area has often been slowed by - amongst other things - the challenge of obtaining approval to test and deploy these installations and the lack of detailed quantitative data as to their impact on the environment (Copping et al., 2018; Simas et al., 2015 and see Galparsoro et al., 2021 for a comprehensive summary of challenges). In fact, the impact of individual novel devices on marine species, habitats and hydrological systems remains largely unknown and this represents a block to the speed of development and a financial challenge due to the requirements of consenting processes (Peplinski et al., 2021). While certainty about the impacts of the devices is some way off, there is an opportunity in the meantime to revisit consenting processes in order to determine whether changes to these could help to release this bottleneck. In addition, the aim of the European Green Deal (European Commission, 2019) is for the EU to be climate-neutral by 2050, and part of that vision is for offshore renewable energy to play a key role in sustaining the blue economy (European Commission, 2021).

While consenting processes for novel technologies should be streamlined and scientifically robust, the challenge lies in balancing this requirement with the urgent need to make progress as climate change accelerates. The ‘precautionary principle’ (UN, 1992, Art. 191 TFEU), a key principle of international and EU law, is often applied in ORE consenting because of the *potential* risk associated with ORE devices and/or of the uncertainty associated with their impacts and interactions with the environment (Galparsoro et al., 2021). This has led to a situation where consenting processes have become very onerous on developers, requiring the collection of detailed data for both pre- and post-installation phases, sometimes to an extent that is considered dis-proportionate to the proposed development (Boehlert and Gill, 2010; Copping et al., 2018). The precautionary principle has therefore been blamed for stalling or halting the development of ORE technologies, whilst not helping either to increase scientific certainty or to improve decision-making within a reasonable timescale.

A. *Adaptive Management*

One solution to the issues outlined above is the use of Adaptive Management (AM), a term first used by Holling (1978) referring to a now widely-used learning-based process, whereby management approaches can be adapted as lessons are learned throughout a project. Using AM, the collection of regular monitoring data both informs any adaptations made and reduces scientific uncertainty in future management decisions. For example, if AM is used to manage a newly-installed ORE device, data gathered during this process can then be used to improve the scientific understanding of its interaction with the environment to inform similar future projects. Essentially, AM can be summarised in several steps (from Williams et al., 2009). There are five initial steps:

1. Stakeholder involvement,
2. Objectives – Identify clear, measurable and agreed upon management objectives to guide decision-making and assess the effect of management actions,
3. Identify a set of management alternatives for decision-making,
4. Monitoring protocols and models that will detect changes in natural resource status,
5. Implementation of monitoring plans.

An iterative phase then involves three additional steps which should be applied in a cyclical manner:

6. Decision-making – Selection of management action based on management objectives,
7. Implementation of monitoring to track resources dynamics and response to management actions,
8. Assessment of management actions – Comparison of predicted and observed changes.

Hanna et al. (2016) identified some unique features of AM that make it stand out from other decision-making processes. Firstly, it addresses scientific uncertainty by using a question-driven approach which can facilitate input from multiple stakeholders. Secondly, it is adaptable and flexible according to the new information generated by the process and finally, the process is iterative such that a feedback loop of information and data improves understanding over time. These three attributes mean that AM lends itself well to projects involving novel hypotheses or technologies.

B. *Risk-based Approaches within Adaptive Management*

One aspect of AM is the incorporation of Risk-Based Approaches (RBA), whereby an assessment of risk is used in the decision-making process when managing a project. Risk-based procedures already play an explicit and important role in a number of environmental regulations and associated guidance documents in various countries (Norris et al., 2014). Examples include the REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation (European Commission, 2006), the Environmental Liability Directive (European Commission, 2004), the Regulation on the prevention and management of the introduction and spread of invasive alien species (European Commission, 2014), the Water Framework Directive (European Commission, 2000) and the Floods Directive (European Commission, 2007), amongst others. In recognition of the challenges posed by the implementation of the EC Marine Strategy Framework Directive (MSFD; European Commission, 2008) over large spatial scales, the provision for a Risk-Based Approach was incorporated in recent years (European Commission, 2017) to "enable Member States to focus their efforts on the main anthropogenic pressures affecting their waters". Although RBAs have not been adopted extensively of yet, and a universally agreed method for their use in the ORE space requires more research (Galparsoro et al., 2021) there is some evidence from other contexts that they could help to improve both coherence and regional cooperation (e.g. Verling et al., 2021; Hollatz et al., 2021; RAGES, 2021). Previous studies have highlighted the role that RBAs could have in consenting processes (Koppel et al., 2014; Le Lievre and O'Hagan, 2015; Le Lievre et al., 2016) and in particular, Le Lievre et al. (2016) highlighted the complexity of the interplay between Adaptive Management (AM) and the precautionary principle in the use of an RBA to consenting for Offshore Renewable Energy. It is clear, however that RBA could assist in reducing the perceived paralysing effect of the precautionary principle and could clear the way for more streamlined and timely development of ORE projects. The purpose of this paper is to explore the use of RBA further in the ORE space and to:

- **Review** the current state of knowledge on the use of RBA in ORE consenting processes and identify the most relevant approaches.
- **Analyse** the similarities and differences between the different RBA used to date.
- **Examine** the extent to which RBA are used in Ireland, France, Spain and Portugal (SafeWAVE countries) at present.
- **Make recommendations** as to what further work is needed to advance this area.

II. Summary of Risk-Based Approaches Relevant to ORE

A number of key RBAs have been developed for practical use in implementation of different policies globally. The most relevant of these have been summarised below, along with a description of their application.

C ISO Risk Standards

The International Standards Organisation (ISO) has published both a series of guidelines for risk management (ISO, 2009) and a standard for risk management which may be applied to risk in any context (ISO, 2018). ISO 31000 sets out the principles (clause 4), framework (clause 5) and process (clause 6) for risk management. ISO 31010 sets out a detailed methodology for the risk management process including a non-exhaustive suite of potential tools and techniques which can be applied to risk management (0).

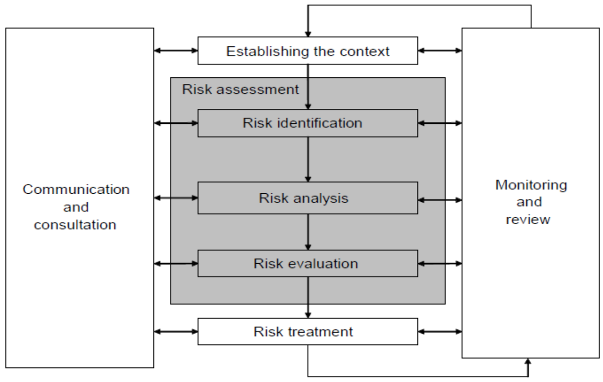

Fig 1. The Risk Assessment approach from ISO Standard 31010 (from ISO, 2009).

This risk assessment approach has already been tested at different spatial scales for Ecosystem Based Management systems (e.g. Sardá et al., 2015; 2017), and has been found to be useful for interpretation of data from experts, indicators and ecosystem models (Bland et al., 2018). The RAGES project (http://www.msfd.eu/rages/rages.html) developed and tested a robust risk-based methodology which brought together the legal articles of the MSFD, a standard methodology based on ISO risk assessment standards and harmonised this with the conceptual frame of the DAPSI(W)R(M)[1] (Elliott et al., 2017). The process was then tested on two descriptors of the MSFD, Descriptor 2 (Non-Indigenous Species) and Descriptor 11 (Underwater Noise). While some of the components of these applications may well be relevant, the ISO Risk system has not yet been directly tested for use in the ocean energy arena. However, these risk standards have formed the basis of a number of other RBAs and they also represent the only current international standard around Risk Assessment and therefore it is important to include them in any consideration of risk assessment.

D The Survey-Deploy-Monitor-Approach (SDM)

The Survey-Deploy-Monitor guidance (Marine Scotland, 2016) was developed by the Scottish Government specifically to provide regulators and developers with an efficient risk-based approach for taking forward wave and tidal energy proposals. The approach focusses on the gathering of baseline data and then on the identification of post-installation impacts through the collection of monitoring data post-deployment. 0 was created to summarise the process graphically.

[1] DAPSI(W)R(M) (pronounced *dap-see-worm*) in which **D**rivers of basic human needs require **A**ctivities which lead to **P**ressures. The **P**ressures are the mechanisms of **S**tate change on the natural system which then leads to **I**mpacts (on human **W**elfare). Those then require **R**esponses (as **M**easures) (see Elliott et al., 2017).

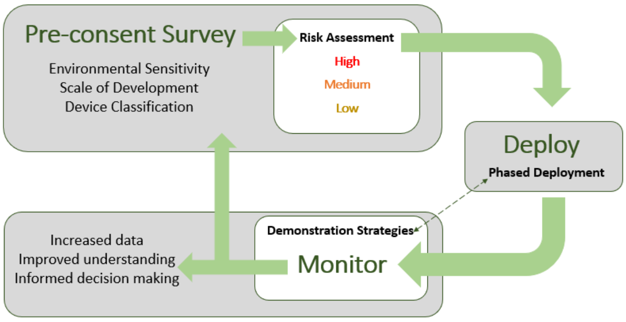

Fig 2. A graphical representation of the Survey-Deploy-Monitor process.

The process is designed "*to enable novel technologies whose potential effects are poorly understood to be deployed in a manner that will simultaneously reduce scientific uncertainty over time whilst enabling a level of activity that is proportionate to the risks*". The guidance makes a distinction between:

- those proposed developments for which there are sufficient grounds to seek determination on a consent application based on a lesser amount of wildlife survey effort and analysis to develop site characterisation pre-application, and
- those proposed developments where the combined site sensitivities, technology risk and project scale make a greater level of site characterisation appropriate. It then highlights how those developments will be deployed and monitored.

Importantly, the SDM process includes 'Demonstration Strategies', which use a case-study approach to tackle areas of uncertainty. By pooling resources, the results from these strategies may inform a number of projects, therefore allowing increased efficiency and sufficient effort to help deliver robust conclusions. Deployments can be made in a phased manner if deemed necessary, and again the Demonstration Strategies can be used to inform decisions to move to subsequent phases.

A. *The Environmental Risk Evaluation System (ERES)*

An Environmental Risk Evaluation System (ERES) was developed by Copping et al. (2015) specifically to allow preliminary assessments of risks associated with ORE devices but also to provide a framework for the incorporation of any data collected in the future on the impacts of ORE devices with the environment. The ERES system was tested on seven different case studies in marine waters and this is described in detail in Copping et al., 2011 and Copping & Hanna, 2011. The process takes account of the fact that the risk level is very much dependent on the nature of the Stressor-Receptor interaction itself and therefore makes a distinction between episodic (e.g. rare but potentially catastrophic oil spillage from a vessel caused by a device), intermittent (e.g. fish and turbine interactions only occurring when fish are present) and chronic (e.g. toxicity from antifouling paint) risk scenarios. The steps in an ERES analysis include screening for a consequence and probability analysis, and there are also further steps which define, manage, and communicate risk (0).

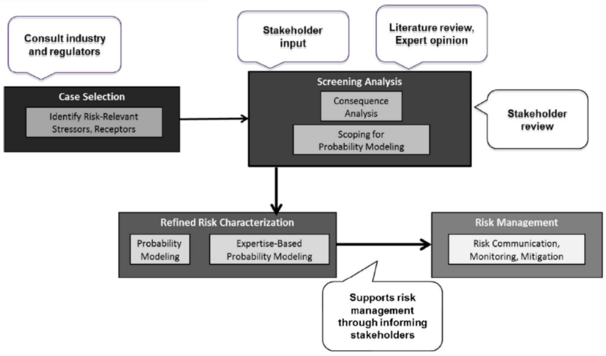

Fig 3. The ERES approach as outlined (from Copping et al., 2015).

The selection of suitable case studies for which the Stressor-Receptor relationship can be defined sufficiently forms a very important aspect of the ERES process and this is inherently limited by the number of specific devices and receptors that have been examined and by the lack of field data to determine the likelihood of each interaction.

E *The Risk Retirement Approach*

The Risk Retirement process developed by Copping et al., (2020) is based on the principle that once the risk associated with a stressor-receptor interaction is considered sufficiently low, then that risk can be 'retired'. The term is used in the ORE and other (e.g. National Academy of Sciences, Engineering and Medicine, 2018) industries to refer to circumstances where key stressor–receptor interactions are sufficiently understood to remove the need for a detailed investigation for each proposed ORE project. The steps of the process (shown in 0) involve defining the risk (stressor-receptor combination), examining existing data and collecting new data where needed and applying and finally testing mitigation strategies before making a decision to 'retire' a risk. The aim of the process therefore is not simply to identify a risk; it is in fact to collate information about stressor-receptor relationships for consenting purposes and to provide a structure whereby experts can evaluate whether a risk can be 'retired' or ruled out. This information can then be collated to be used to inform future consenting applications. The Risk Retirement process described in Copping et al., (2020) was developed specifically for the ORE industry (although it has a wider application) and allows for a strategic and long-term approach to consenting.

Fig 3. The steps of the Risk Retirement approach (from Copping et al., 2020).

F Ecological Risk Assessment (ERA) Framework

The Ecological Risk Assessment Framework outlined in the work of Galparsoro et al., 2021 uses expert judgement, literature review and a web tool[1] to capture the interactions between a wave farm and the marine environment. It is adapted from Cormier et al. (2018) which was ultimately based on the ISO 31000 standard (ISO, 2018) and has already been put into practical use in the context of Marine Spatial Planning (MSP) by Stelzenmüller et al., (2010). For its use in wave energy consenting, a four-stage process was developed (illustrated in 0) whereby firstly a **Risk Identification** step specifies the intensity and likelihood of the pressure as well as the sensitivity of the ecosystem component. Next, a **Characterisation** step specifies the likely impact on the ecosystem element, followed by an **Assessment** step which identifies the most relevant pressures and most likely ecosystem elements to be affected and examines overall risk. Finally, the **Management** step identifies the management measures to reduce or mitigate for hazards.

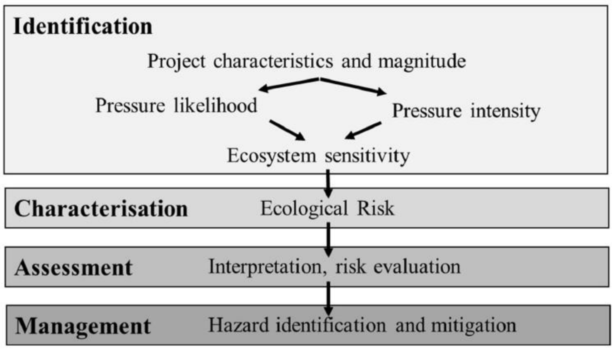

Fig 4. The steps of the Ecological Risk Assessment approach (from Galparsoro et al., 2021).

III. UNDERSTANDING THE RELATIONSHIPS BETWEEN RBAS

G Language and definitions

There are many links and similarities between the five RBAs outlined in Section 2 above. Importantly, most of the frameworks explicitly define risk in a similar way (see Table 1) and all provide a systematic approach to considering risk.

TABLE 1. THE DEFINITIONS OF RISK USED IN THE FIVE RBAS, AND AN INDICATION OF WHETHER THEY WERE DEVELOPED IN THE CONTEXT OF OFFSHORE RENEWABLE ENERGY CONSENTING.

Risk Approach	Risk Definition	Developed for ORE?
ISO Risk Standards	Defined as "the effect of uncertainty on management objectives"	No
Survey-Deploy-Monitor	Not explicitly defined but it is stated that Survey-Deploy-Monitor "....is designed to enable novel technologies whose potential effects are poorly understood to be deployed in a manner that will simultaneously reduce scientific uncertainty over time whilst enabling a level of activity that is proportionate to the risks"	Yes
Ecological Risk Evaluation System	Defined as "the probability of occurrence of an action and the severity of the effect"	Yes
Risk Retirement Process	The work cites the following definition of risk: "....the intersection of the likelihood or probability of an event occurring, and the consequences of the event if it were to occur"	Yes
Ecological Risk Assessment Framework	Ecological Risk Assessment is defined as "a flexible process for organising and analysing data, assumptions, and uncertainties to evaluate the likelihood (probability) of adverse ecological effects that may have occurred or may occur as a result of exposure to one or more stressors related to human activities" based on Hope (2006)	Yes

A number of important points emerge from an examination of the five frameworks together:

- All of these risk approaches explicitly tackle the **receptor-stressor** relationships.
- All of them perform some sort of **risk evaluation** process in order to identify the most critical risks.
- Some of them (e.g., Copping et al., 2020) focus on **removing risks**, but ultimately have the same goal – to identify the most pertinent risks and to address these.
- An assessment of the likelihood and consequence of a receptor-stressor interaction is a common theme in the majority of these approaches.

There are several examples where steps within the different approaches are equivalent or almost equivalent, but have been given different titles:

- **Risk Identification** of the ERA approach is approximately equivalent to the **Risk Analysis** step in the ISO standards.
- **Risk Assessment** step of the ERA Approach is approximately equivalent to the **Risk Evaluation** step of the ISO.

[1] https://aztidata.es/wec-era/

- **Risk Management** of ERA is approximately equivalent to the **Risk Treatment** step of the ISO.
- The Risk Retirement process appears approximate to the concept of **Preliminary Analysis** within the ISO standard (see ISO 31010 (ISO, 2009), pg. 15); both of these have as their aim the need to **remove low or non-existent risks.**
- The value of incorporating **expert judgement** is acknowledged (in Galparsoro et al., 2021), particularly at the early screening stage.

The evolution of several different approaches globally to the same problem (in this case for consenting for Offshore renewable energy projects) is in fact an indication of the pervasive and urgent requirement for this issue to be addressed. Although the development of these different frameworks might be viewed as an impediment to progress, each of the RBAs reviewed here focusses on the issue from a slightly different perspective, and in so doing provides a greater understanding and allows a more in-depth interpretation of the requirement for risk-based consenting processes. Leaving space for this increased understanding to develop means that any harmonized approach emerging in the future will incorporate the crucial elements and should therefore be more effective.

Many of the points above concern the use of language and the use of varied terms to refer to equivalent or quasi-equivalent steps. This varied use of language adds to the complexity of using such frameworks for regulators and developers alike and may be a deterrent in many cases, limiting uptake. The language of Risk-based approaches has become more complex as new and slightly different methods are developed for various purposes. The increased research interest and subsequent refinement of risk frameworks has greatly assisted with the understanding of risk assessment, and indeed in some cases has succeeded in unpicking the complexity of it (e.g., the work of Galparsoro et al., 2021 claims to move towards the capture of additional complexity compared with earlier approaches).

H Finding the key crosswalks between RBAs

0 shows a diagrammatic representation of the relationships between the five approaches and illustrates that there are many categories that apply to several of the frameworks, although the terms used vary from approach to approach. Four clear patterns emerge from this visualisation:

1. The ERES, ERA and ISO frameworks have much in common in that all contain a number of steps moving from identification of the receptors and stressors, to a description of risk via assessment of consequence and likelihood and then an evaluation of relative risk. In this sense, these frameworks provide a detailed approach to assessing the risk itself.
2. The Risk Retirement and Survey-Deploy-Monitor Approach contain some elements for which there are not direct equivalents in the other three frameworks. This is due to the '**deploy'** and '**monitor'** aspects of the SDM and the **collection of additional data** and **testing of novel mitigation** aspects of Risk Retirement, which are rooted in the practical application of an RBA and are more focussed on the mechanistic feedback of information required for Adaptive Management.
3. The Pre-consent Survey step of the Survey-Deploy-Monitor process is not prescriptive, and it is likely that it is sufficiently all-encompassing to allow many of the steps from the ERA, ERES and ISO frameworks to be nested into it.
4. The Risk Retirement framework contains a bridge between the more prescriptive approach of the ERES, ERA and ISO frameworks and the less detailed Survey-Deploy-Monitor process.

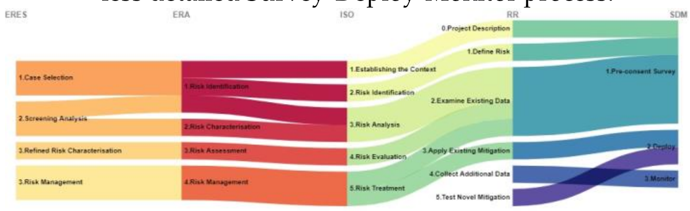

Fig 5. An illustration of the crosswalks and links between the different RBAs described.

IV. Creating a simple stepwise RBA process

The next step of this work explored in more detail the possibility of producing a set of guidance for the use of RBA in ORE consenting processes. To do this, we first aimed to identify a common a **risk-based framework.**

Among the RBAs examined above was the Ecological Risk Assessment (ERA) framework described by Galparsoro et al. (2021). This ERA framework also formed the basis of the Decision Support Tool developed within SAFEWave (Galparsoro et al., 2022). Therefore, to ensure consistency of project outputs, the steps of the risk-based framework presented here are equivalent to those of Galparsoro et al. (2021) but are presented in a simpler fashion with clear links to the other frameworks examined.

There are several examples of specific steps within the different approaches which are equivalent or almost equivalent but have been given different names. There are also a number of key considerations that are common between all the approaches, though they have been called by different terms or divided between steps in various ways. These varied interpretations - whilst valid and essential in developing the ideas behind RBAs - have had the undesired effect of adding to the complexity of such frameworks for regulators and developers and may actually be a deterrent to their use. The simplified stepwise process presented here aims to take the key elements of all existing approaches, but to present them in a more accessible way for practical use.

I Risk-Based Approach process and steps

Using the understanding gathered from a detailed examination of the existing frameworks, the simple stepwise approach proposed here consists of four steps. 0 provides a visual representation of this stepwise approach and it each step is described in detail below.

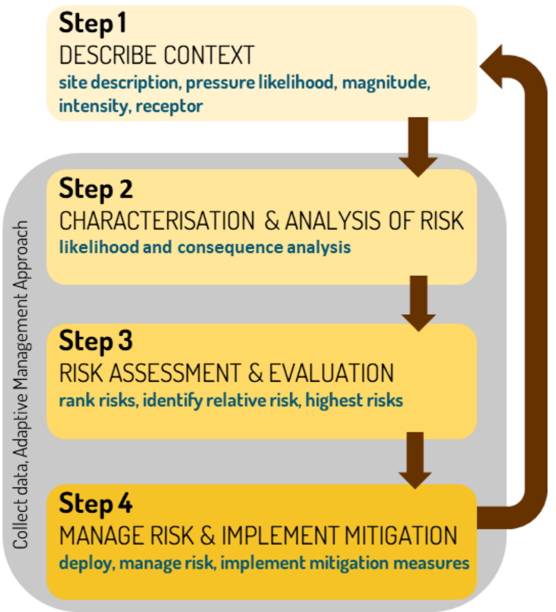

Fig 6 Diagram showing the stepwise Risk-Based Approach process and steps.

1) STEP 1. Describe Context and Identify Risk

The main tasks within this step include providing a background to the scenario such as a site and project description. A project description involves for example the type of ORE device, production capacity, number of devices etc. This provides an idea of the magnitude of the project and of the types of pressures that can be produced by different ORE technologies. The site description refers to the ecosystem components that might be present in the area, and the associated vulnerability to the potential pressures produced by the project. Crucially, this section also includes a description of the risks identified, by describing and identifying:

- the potential pressures (likelihood and intensity), and
- the receptors, ecosystem components such as habitats and species, that are potentially sensitive to pressures.

This step can be detailed, or very simple, but in order to make it as comprehensive as possible, it is imperative to understand **what is meant by 'risk' in each particular case.** Note that this process may reveal that there are several different pressure and receptor **combinations** to take into account. In considering pressures, it is also important that factors such as intensity and duration be taken into account where information is available.

2) STEP 2. Analyse Risk

-For each pressure and receptor combination identified in Step 1, this step undertakes a **likelihood** analysis and a **consequence** analysis. A likelihood analysis considers the chance that a pressure and a particular receptor (e.g., species or habitat) will overlap in space (and by extension in time). A consequence analysis considers the potential outcome or result of that overlap (i.e., environmental impact or changes on the environmental status). The aim is to produce a **quantitative measure** of both of these parameters which (in the next step) can be used together to calculate **an overall measure of risk**. This is the most complex of all the steps as it requires a process to be devised to determine the likelihood and consequence measures in a particular situation. Variations in factors such as pressure intensity and duration can impact both the likelihood and consequence scores. It may be necessary to calculate different scores based on varying levels of pressure intensity, for example. Additionally, the cumulative pressures should be also considered when implementing a RBA (e.g., Stelzenmüller et al., 2018; 2020) and it links to the wider Environmental Impact Assessment process, which requires cumulative impacts to be identified. .

3) STEP 3. Evaluate Risk

This step takes the information gathered in Step 2 and uses it to determine the **relative risk.** Relative Risk is obtained by taking the product of the likelihood and consequence analyses in Step 2 (**likelihood x consequence**) for different combinations of pressure and receptor and comparing the results with each other to identify those risks that are most significant. This concept is illustrated in 0 below.

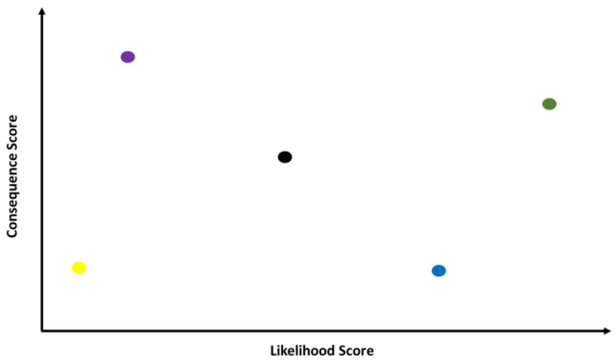

Fig 7. A visual representation of Relative Risk, whereby the results of Step 2 are graphically represented and can be compared to one another. The coloured circles represent different scenarios, for example, a high likelihood and high consequence situation (green circle) and a high likelihood but low consequence (blue circle). Each of these scenarios would require the adoption of different management and risk mitigation measures.

4) STEP 4. Manage Risk and Implement mitigation measures

This step refers to the actions taken pre-, during and post-deployment to manage the risks identified in the preceding steps. This step will be specific to a particular setting and will vary depending largely on the environmental and regulatory factors. Importantly, this step also includes the testing of reduction measures and novel mitigation strategies in order to increase knowledge and expertise. This feedback is represented in Figure 6 through the large arrow on the right.

Alongside each of these four steps is the overarching consideration of **new data collection (monitoring),** which does not fit into any particular step – in fact the opportunity to collect new information exists for all steps. This concept is strongly emphasised in the Survey Deploy Monitor (SDM) and Risk Retirement (RR) approaches (via the 'Collect Additional Data' in RR and 'Monitor' in SDM) but less so in the others. Emphasising the need for this consideration draws the process further into the Adaptive Management space and allows knowledge to improve and influence the other parts of the process.

J Relationship between the stepwise approach and the five core RBAs

A relationship can be suggested between the stepwise process proposed here and each of the five core RBAs previously proposed by other authors. However, it is important to note that these relationships are not rigidly defined and the boundaries between them can be considered somewhat fuzzy. However, Fig. 80 aims to illustrate the proposed relationship between each step relative to those of the core RBAs. The aim is to help define each step insofar as possible and to assist in directing the user to the appropriate aspect of the underlying approaches if they would like to obtain more detail or refer to examples of the risk approach in action.

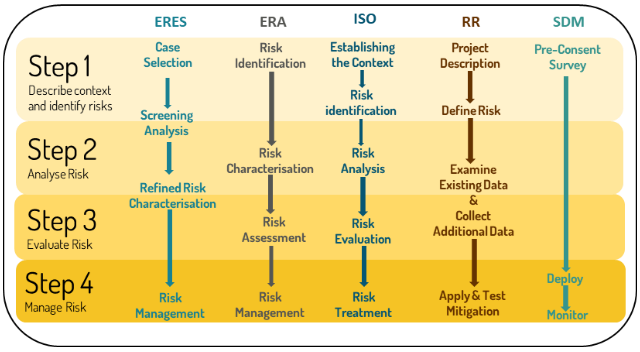

Fig 8. Showing the suggested relationships between the steps in the simple stepwise approach and the five core RBAs that contributed to this work.

V. Exploring RBA in Practice: Key Findings

This work will be developed further to include the inputs from further consultation with stakeholders to produce a guidance document for the use of RBA in consenting processes. To increase understanding of the use of RBAs in practice in the different Member States represented by the SafeWAVE project, partners were asked a series of questions about their own experiences of the consenting process in their country (see Annex I). The information received was practitioner-based, in that the respondents were involved either in development or testing of WECs (and not in their regulation). Although this meant that the process did not explore the situation at a national level, it did provide an insight into the extent to which RBAs are considered in the planning process on the ground and explored whether there is an appetite at present for guidance or a clearer understanding of RBAs in consenting processes. The following points highlight the most significant findings:

- Overall, RBAs to consenting have not been used historically for OREs in Ireland, Portugal, France or Spain.
- There is an awareness that the interest in RBAs has increased in the last decade and that they are being employed in other aspects of environmental management.
- There does not appear to be a strong allegiance to one RBA over another.
- In some cases, RBAs were not knowingly used in consenting processes but there was a feeling that risk forms part of the decision-making process in an informal way.
- There is a feeling that guidance around the use of RBAs would be useful into the future.
- Due to the wide range of device types and the diversity of environmental conditions in which they will be deployed, any risk-based approach needs to be flexible and adaptable.
- Some consenting processes were completed for test sites over a decade ago and were based on learnings from ORE projects overseas at that time. These authorisations continue to apply now (providing the characteristics of devices are included in the "envelope" described in the Environmental Impact Assessment issued at that time).
- To date, provision has not been made for cumulative effects at the time of consenting, but the importance of considering this is seen as being important into the future.

Detailed information about the consenting processes in Spain and Portugal can be found in WESE Project Deliverable 4.2 (Bald et al., 2020). Further consultation will be required with regulatory and other stakeholders in order to produce a useful guidance document which considers consenting processes in the context of a Risk-based Framework.

References

[1] J Bald and M. Apolonia. (2020). Deliverable 4.2 Review of consenting processes for wave energy in Spain and Portugal focusing on risk-based approach and Adaptive Management. Deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 58 pp.

[2] L.M. Bland, K.E. Watermeyer, D.A. Keith, E. Nicholson, T.J. Regan and L.J. Shannon. Assessing risks to marine ecosystems with indicators, ecosystem models and Experts. *Biological Conservation* vol. 227, pp. 19–28, 2018.

[3] G. Boehlert and A. Gill. Environmental and Ecological Effects of Ocean Renewable Energy Development: A Current Synthesis. *Oceanography* vol. 23, no. 2, pp. 68–81, 2010.

[4] A.E. Copping, K.M. Blake, R.M. Anderson, L.C. Zdanski, G.A. Gill and J.A. Ward. Screening analysis for the environmental risk evaluation system: environmental effects of marine and hydrokinetic energy development. PNNL-20805. Pacific Northwest National Laboratory, Seattle Washington, 2011.

[5] A.E. Copping, and L.A. Hanna. (2011). Screening analysis for the environmental risk evaluation system: environmental effects of offshore wind energy. PNNL-20962. Pacific Northwest National Laboratory, Seattle Washington, 2011.

[6] A.E. Copping, L.A. Hanna, B. Van Cleve, K.M. Blake and R. M. Anderson. Environmental Risk Evaluation System— an Approach to Ranking Risk of Ocean Energy Development on Coastal and Estuarine Environments. *Estuaries and Coasts*, vol. 38, pp. 287–302, 2015.

[7] A.E. Copping. The State of Knowledge for Environmental Effects: Driving Consenting/Permitting for the Marine Renewable Energy Industry. Pacific Northwest National Laboratory: Richland, Washington, 2018.

[8] A.E. Copping, M.C. Freeman, A.M. Gorton and L.G. Hemery. Risk retirement—decreasing uncertainty and informing consenting processes for marine renewable energy development. *Journal of Marine Science and Engineering* vol. 8, pp. 172R

[9] R. Cormier, V. Stelzenmüller, I. Creed, J. Igras, H. Rambo, U. Callies and L. Johnson. The science-policy interface of risk-based freshwater and marine management systems: From concepts to practical tools. *Journal of Environmental Management* vol. 226, pp. 40–346, 2018.

[10] M. Elliott. D. Burdon, J. Atkins, A. Borja, R. Cormier, V. de Jonge and R. Turner. "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management. *Marine Pollution Bulletin* vol. 118 no. 1-2, pp. 27-40, 2017.

[11] I. Galparsoro, M. Korta, I. Subirana, A. Borja, I. Menchaca, O. Solaun, I. Muxika, G. Iglesias and J. Bald (2021) A new framework and tool for ecological risk assessment of wave energy converters projects I. *Renewable and Sustainable Energy Reviews* 151 (2021) 111539.

[12] I. Galparsoro, G. Mandiola, R. Garnier, I. de Santiago, E. Villarín, G. Iglesias, I. Machado, T. Soulard, E. Le Bourhis, L. Zubiate, I. Menchaca and J. Bald. Development of a model for the identification of suitable areas for the development of wave energy projects in the European Atlantic region in the context of maritime spatial planning and its implementation into a Decision Support Tool. The corporate deliverable of the SafeWAVE Project co-funded by the European Climate, Infrastructure and Environment Executive Agency (CINEA), Call for Proposals EMFF-2019-1.2.1.1 - Environmental monitoring of ocean energy devices. 50 pp + Annexes, 2022 http://dx.doi.org/10.13140/RG.2.2.29874.07360

[13] L. Hanna, A. Copping, S. Geerlofs, L. Feinberg, J. Brown-Saracino, P. Gilman, F. Bennet, R. May, J. Köppel, L. Bulling and V. Gartman. Assessing Environmental Effects (WREN): Adaptive Management White Paper. Report by Berlin Institute of Technology, Bureau of Ocean Energy Management (BOEM), Marine Scotland Science, Norwegian Institute for Nature Research (NINA), Pacific Northwest National Laboratory (PNNL), and U.S. Department of Energy (DOE). 2016.

[14] C. Hollatz, J-M. Brignon, C. Bartilotti, V. Chapon, M. Tuaty-Guerra, J. Lobo Arteaga, I. Cardoso, P. Chainho, F. Gizzi, J. Monteiro, J. Macedo, M.J. Gaudêncio, J. Canning-Clode and G. Carreira. WP3 Application of Risk-Based Approach to Non-Indigenous Species (Descriptor 2). Project RAGES: Risk-Based Approaches to Good Environmental Status. EU Grant Agreement No. 110661/2018/794607/SUB/ENV.C.2. Deliverable 3.4 - Sub-regional risk assessment for Descriptor 2, 81p + 2 Annexes, 2021. www.msfd.eu/rages.

[15] C. Hollatz, J-M. Brignon, C. Bartilotti, V. Chapon, M. Tuaty-Guerra, J. Lobo Arteaga, I. Cardoso, P. Chainho, F. Gizzi, J. Monteiro, J. Macedo, M. J. Gaudêncio, J. Canning-Clode, and G. Carreira. WP3 Application of Risk-Based Approach to Non-Indigenous Species (Descriptor 2). Project RAGES: Risk-Based Approaches to Good Environmental Status. EU Grant Agreement No. 110661/2018/794607/SUB/ENV.C.2. Deliverable 3.4 - Sub-regional risk assessment for Descriptor 2, 81p + 2 annexes, 2021. www.msfd.eu/rages

[16] B.K. Hope. An examination of ecological risk assessment and management practices. *Environmental International* vol. 32, pp. 83–95, 2006.

[17] ICES. Workshop on Cumulative Effects Assessment Approaches in Management (WKCEAM). ICES Science Reports pp. 33, 2019

[18] ISO. International Standard. Risk Management - Risk assessment techniques. Edition 1.0 2009-11, 2009. International Standards Organisation, Geneva.

[19] ISO. International Standard. Risk Management - Guidelines. Second Edition 2018-02, 2018. International Standards Organisation, Geneva.

[20] J. Koppel, M. Dahmen and J. Helfrich. Cautions but Committed: moving Towards Adaptive Planning and Operation Strategies for Renewable Energy's Wildlife Implications. *Environmental Management*, vol. 54, no. 4, pp. 744-755, 2014.

[21] S. Korpinen and J. Andersen. A Global Review of Cumulative Pressure and Impact Assessments in Marine Environments. *Frontiers of Marine Science* vol. 3, pp. 153, 2016.

[22] C. Le Lièvre and A.M. O'Hagan. Legal and institutional review of national consenting systems, Deliverable 2.2, RICORE Project. 46 pp, 2015.

[23] C. Le Lièvre, A.M. O'Hagan, R. Culloch, F. Bennet and I. Broadbent. Deliverables 2.3 & 2.4 Legal feasibility of implementing a risk-based approach and compatibility with Natura 2000 network. RICORE Project. 53 pp, 2016.

[24] S.E. Jorgensen and B.D. Fath (eds). Encyclopedia of Ecology. Elsevier, Amsterdam, 2018.

[25] Marine Scotland. Survey, Deploy and Monitor Licensing Policy Guidance, 2016, 11 pp. Available online: https://www2.gov.scot/Topics/marine/Licensing/marine/Applications/SDM.

[26] M.L. Martínez, G. V´azquez, O. P´erez-Maqueo, R. Silva, P. Moreno-Casasola, G. Mendoza-Gonz´alez, J. L´opez-Portillo, I. MacGregor-Fors, G. Heckel, J.R. Hern´andez-Santana, J.G. García-Franco, G. Castillo-Campos and A.L. Lara-Domínguez. A systemic view of potential environmental impacts of ocean energy production. *Renewable and Sustainable Energy Reviews* vol. 149, pp. 111332, 2021.

[27] National Academies of Sciences, Engineering, and Medicine. Guidelines for Managing Geotechnical Risks in design Build Projects. The National Academies Press: Washington, DC, USA, 2018.

[28] J. Norris, D. Cowan, C. Bristow, D. Magagna and J. Giebhardt. D4.7 Best Practice Report on Environmental Monitoring and New Study Techniques. In Marine Renewables Infrastructure Network for Emerging Energy Technologies (MARINET); 2014; p. 105. Available online: https://tethys.pnnl.gov/publications/d47-bestpractice-report-environmental-monitoring-new-study-techniques (accessed on 3 January 2020).

[29] W.J Peplinski, J. Roberts, G. Klise, S. Kramer, Z. Barr, A. West and C. Jones. Marine Energy Environmental Permitting and Compliance Costs. *Energies* vol. 14: pp.4719, 2021.

[30] RAGES. Developing a Risk-based Approach to Good Environmental Status. RAGES Deliverable 2.3. GRANT AGREEMENT Nº 110661/2018/794607/SUB/ENV.C.2: Risk Based Approaches to Good Environmental Status Project, 2021. www.msfd.eu/rages

[31] R. Sardá, J.F. Valls, J. Pintó, E. Ariza, J.P. Lozoya, R.M. Fraguell, C. Martí, J. Rucabado, J.R. Ramis and J.A. Jimenez. Towards a new Integrated Beach Management System: The Ecosystem-Based Management System for Beaches. *Ocean & Coastal Management* vol. 118, pp. 167-177, 2015.

[32] R. Sardá, S.R. Moren, C. Dominguez-Carro. and J.M. Gili. Ecosystem Based Mangement for Marine Protecte Areas: A Network Perspective. In: Management of Marine Protect Areas (PD Goriup, Ed). John Wiley and Sons, 2017. pp 145-162.

[33] V. Stelzenmüller, H.O. Fock, A. Gimpel, H. Rambo, R. Diekmann, W.N. Probst, U. Callies, F. Bockelmann, H. Neumann, I. Kröncke. Quantitative environmental risk assessments in the context of marine spatial management: current approaches and some perspectives. *ICES Journal of Marine Science*, vol. 72, no. 3, pp. 1022-1042, 2015.

[34] V. Stelzenmüller, M. Coll, A.D. Mazaris, S. Giakoumi, S. Katsanevakis, M. E. Portman, R. Degen, P. Mackelworth, A. Gimpel, P.G. Albano, V. Almpanidou, J. Claudet, F. Essl, T. Evagelopoulos, J.J. Heymans, T. Genov, S. Kark, F. Micheli, M. G. Pennino, G. Rilov, B. Rumes, J. Steenbeek, H. Ojaveer. A risk-based approach to cumulative effect assessments for marine management. *Science of The Total Environment*, vol. 612, pp. 1132-1140, 2018.

[35] V. Stelzenmüller, M. Coll, R. Cormier, A.D. Mazaris, M. Pascual, C. Loiseau, J. Claudet, S. Katsanevakis, E. Gissi, A. Evagelopoulos, B. Rumes, S. Degraer, H. Ojaveer, T. Moller, J. Giménez, C. Piroddi, V. Markantonatou, C. Dimitriadis. Operationalizing risk-based cumulative effect assessments in the marine environment. *Science of The Total Environment*, vol. 724, pp. 138118, 2020.

[36] United Nations. Declaration of the UN Conference on Environment and Development. UN, 1992. Doc.A/CONF.151/26/Rev.1 (Vol. 1), Annex I (Aug. 12, 1992).

[37] E. Verling, R. Miralles Ricós, M. Bou-Cabo, G. Lara, M. Garagouni, J-M Brignon and T. O'Higgins. Application of a risk-based approach to continuous underwater noise at local and subregional scales for the Marine Strategy Framework Directive. *Marine Policy,* vol. 134, pp. 104786, 2021.

[38] B.K. Williams, R.C. Szaro and C.D. Shapiro. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington DC, USA, 2009. Available from https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf