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Review

Assessing the cumulative environmental effects of marine renewable energy developments: Establishing common ground

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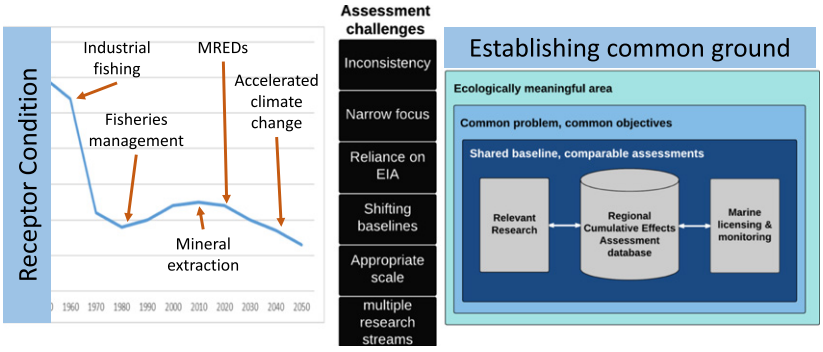
HIGHLIGHTS

- Cumulative environmental effects in the marine realm are reviewed.
- Cumulative environmental assessment approaches are shown to be currently inadequate.
- CEA should be fed data from EIAs, not vice versa.
- A coordinated and multidisciplinary framework of CEA is proposed.
- Coordinated CEA offers robust analysis that frames the wider environmental debate.

GRAPHICAL ABSTRACT



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ABSTRACT

Assessing and managing the cumulative impacts of human activities on the environment remains a major challenge to sustainable development. This challenge is highlighted by the worldwide expansion of marine renewable energy developments (MREDs) in areas already subject to multiple activities and climate change. Cumulative effects assessments in theory provide decision makers with adequate information about how the environment will respond to the incremental effects of licensed activities and are a legal requirement in many nations. In practise, however, such assessments are beset by uncertainties resulting in substantial delays during the licensing process that reduce MRED investor confidence and limit progress towards meeting climate change targets. In light of these targets and ambitions to manage the marine environment sustainably, reducing the uncertainty surrounding MRED effects and cumulative effects assessment are timely and vital. This review investigates the origins and evolution of cumulative effects assessment to identify why the multitude of approaches and pertinent research have emerged, and discusses key considerations and challenges relevant to assessing the cumulative effects of MREDs and other activities on ecosystems. The review recommends a shift away from the current reliance on disparate environmental impact assessments and limited strategic environmental assessments, and a move towards establishing a common system of coordinated data and research relative to ecologically meaningful areas, focussed on the needs of decision makers tasked with protecting and conserving marine ecosystems and services.

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1. Introduction

The cumulative environmental effects (hereafter cumulative effects) of marine renewable energy developments (MREDs) remain highly uncertain (Bailey et al., 2014; Masden et al., 2015; MMO, 2013) and are problematic in light of ambitious renewable energy targets and aspirations to use the seas sustainably (Bergström et al., 2014; Copping et al., 2014). MREDs, defined here as infrastructure developments that generate electricity from wind, wave, tidal and current resources, add to current pressures or introduce novel stressors that may positively or negatively impact marine ecosystems (Gill, 2005; Linley et al., 2009), thus appropriate assessments of the consequences of development are warranted (Gill, 2005). Efforts to reduce uncertainties to acceptable levels are complicated first and foremost by the numerous knowledge gaps about cause-effect relationships between effects and ecosystem components (MMO, 2013; Lindeboom et al., 2015) but also by the many interpretations of what cumulative effects and cumulative effects assessment (CEA) are (Duinker et al., 2012). Revisiting the origins and evolution of CEA provides insight into the wide application of the term observed today and the plurality of approaches applied.

The origins of CEA as a process are closely linked to the formation and rise of environmental impact assessment (EIA). EIA was formalised following the enactment of the National Environmental Policy Act of 1969 (NEPA) in the USA, established in the wake of popular concern and political action linked to environmental degradation caused by rapid industrial and agricultural progress in the 20th century (Glasson et al., 2012; Du Pisani, 2006). EIA is premised on sustainable development, sensu WCED (1987), being desirable, hence the consequences of activities should be accounted for in decision-making before they happen (International Association of Impact Assessment (IAIA), 2009; Glasson et al., 2012). In the late 1970s, it was realised that for EIA to fulfil its potential, approvals for activities needed to consider other activities in close spatial and temporal proximity (Canter and Ross, 2010). NEPA was thus revised in 1978 to explicitly require the assessment of cumulative effects and, over time (1995 in Canada and 1997 in the European Union, for example), environmental legislation in numerous regions of the world has followed suit (Canter and Ross, 2010; Connelly, 2011).

The practise of CEAs received greater attention in the 1980s and 1990s, as litigation was successfully brought against environmental agencies in the USA deemed not to be meeting their responsibility to assess and manage cumulative effects (Canter and Ross, 2010; Schultz, 2012). Scientists working in different fields increasingly realised the fundamental importance of managing cumulative environmental change, leading to transboundary research initiatives resulting in important conceptual and methodological advances (Cocklin et al., 1992; Beanlands and Duinker, 1984; Preston and Bedford, 1988). Ecological principles began to play a role in EIA, for example the focus on a limited set of valued ecosystem components, or receptors (Beanlands and Duinker, 1984). While interpretation of the principle remains problematic (see Ball et al., 2012), the focus on receptors that experience the effects of development over temporal and spatial scales greater than those typically considered by EIAs for individual projects inevitably led to a spotlight on cumulative effects (Duinker et al., 2012; Therivel and Ross, 2007).

Increasing recognition by policy-makers of the role cumulative effects play in shaping marine and terrestrial ecosystems can be observed in the proliferation of legislation requiring regulators to consider cumulative effects (Judd et al., 2015). While the language stipulating CEA and the impetus behind the legislative drivers varies, the intent of the drivers is consistent; to enable effective protection and management of the environment (Judd et al., 2015). Similarly, growing awareness of how an increasing range and intensity of anthropogenic stressors influences the condition and resilience of ecosystems has led to numerous CEAs of one form or another driven by scientific inquiry. However, while the range of drivers has increased, the bulk of information about the cumulative effects of anthropogenic activities applied in environmental planning and management continues to stem from one source, EIAs completed for individual developments (Duinker et al., 2012; OSPAR Commission, 2008). This is problematic, as EIA-led CEA has historically been (e.g. Cooper and Canter, 1997; Cooper and Sheate, 2002) and continues to be highlighted as a weak link within the EIA process (Canter and Ross, 2010; Wärnbäck and Hilding-Rydevik, 2009; Pope et al., 2013), in large part due to the shortcomings of EIAs at identifying the significance of minor activities accumulating to impact valued receptors and the wider environment (Therivel and Ross, 2007; Squires and Dubé, 2013; Duinker and Greig, 2006). Cumulative effects, defined as effects of an additive, interactive, synergistic or irregular nature that are caused by individually minor but collectively significant activities, accumulate over broad temporal and spatial scales (Harriman and Noble, 2008).

The term CEA (including cumulative impact assessments) has thus become an umbrella term that today encompasses a plurality of interpretations and approaches that seek to address a broadly similar problem, that of cumulative environmental change, sensu Spaling and Smit (1993). In the marine environment, where the crux of management is the protection of natural ecological characteristics while delivering