Environmental Impact Assessment Review xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

# The challenges and opportunities in cumulative effects assessment

Melissa M. Foley [a,b,*], Lindley A. Mease [c], Rebecca G. Martone [b], Erin E. Prahler [c], Tiffany H. Morrison [d], Cathryn Clarke Murray [e], Deborah Wojcik [f]

[a] U.S. Geological Survey, Pacific Coastal and Marine Science Center, 400 Natural Bridges, Dr., Santa Cruz, CA 95060, USA
[b] Center for Ocean Solutions, Stanford University, 99 Pacific St., Monterey, CA 93940, USA
[c] Center for Ocean Solutions, Stanford University, 473 Via Ortega, Stanford, CA 94305, USA
[d] ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD, 4811, Australia
[e] WWF-Canada, 409 Granville Street, Suite 1588, Vancouver, BC V6C 1T2, Canada
[f] Nicholas School for the Environment, Duke University, 9 Circuit Dr., Durham, NC 27708, USA

A R T I C L E  I N F O

*Article history:*
Received 5 January 2016
Received in revised form 18 April 2016
Accepted 28 June 2016
Available online xxxx

*Keywords:*
Cumulative effects analysis
Cumulative effects assessment
Baseline
Significance
Scale
Thresholds

A B S T R A C T

The cumulative effects of increasing human use of the ocean and coastal zone have contributed to a rapid decline in ocean and coastal resources. As a result, scientists are investigating how multiple, overlapping stressors accumulate in the environment and impact ecosystems. These investigations are the foundation for the development of new tools that account for and predict cumulative effects in order to more adequately prevent or mitigate negative effects. Despite scientific advances, legal requirements, and management guidance, those who conduct assessments—including resource managers, agency staff, and consultants—continue to struggle to thoroughly evaluate cumulative effects, particularly as part of the environmental assessment process. Even though 45 years have passed since the United States National Environmental Policy Act was enacted, which set a precedent for environmental assessment around the world, defining impacts, baseline, scale, and significance are still major challenges associated with assessing cumulative effects. In addition, we know little about how practitioners tackle these challenges or how assessment aligns with current scientific recommendations. To shed more light on these challenges and gaps, we undertook a comparative study on how cumulative effects assessment (CEA) is conducted by practitioners operating under some of the most well-developed environmental laws around the globe: California, USA; British Columbia, Canada; Queensland, Australia; and New Zealand. We found that practitioners used a broad and varied definition of impact for CEA, which led to differences in how baseline, scale, and significance were determined. We also found that practice and science are not closely aligned and, as such, we highlight opportunities for managers, policy makers, practitioners, and scientists to improve environmental assessment.



## 1. Introduction

In many jurisdictions around the world, resource managers, government agency staff, and consultants (collectively hereafter referred to as "practitioners") assess potential environmental impacts of human activities (e.g., development, resource extraction; hereafter referred to as "projects") through permitting or planning processes that require an environmental impact assessment (EIA) to be completed. There are four main components to most EIA. First, practitioners begin their analysis by scoping the types of project impacts that will be included in their analysis. Second, practitioners designate a baseline (i.e., the condition of the ecosystem relative to human impact at a designated point in time) to compare ecosystem effects with and without the proposed project. Third, practitioners constrain their appraisal by bounding the spatial and temporal extent of potential impacts. And fourth, practitioners determine if the project is expected to significantly impact the ecosystem. The definition of significance varies by jurisdiction, but generally refers to a substantial, unacceptable change in some component of the environment compared to a baseline condition. As part of the EIA process, some jurisdictions also require practitioners to analyze the potential cumulative effects (as opposed to only the individual effects) of the project on the environment.

The cumulative effects of human and natural stressors on ecosystems are recognized as one of the most pressing problems facing coastal and marine habitats around the world (Halpern et al. 2009, Ban et al. 2010, Halpern and Fujita 2013, Parsons et al. 2014, Rudd and Fleishman 2014). Human stressors—the physical, chemical and biological manifestations of human activities in the environment that can affect the structure, function, or well-being of coastal and marine

* Corresponding author at: U.S. Geological Survey, Pacific Coastal and Marine Science Center, 400 Natural Bridges, Dr., Santa Cruz, CA 95060, USA.
*E-mail addresses:* mfoley@usgs.gov (M.M. Foley), lamease@stanford.edu (L.A. Mease), rmartone@stanford.edu (R.G. Martone), tiffany.morrison@jcu.edu.au (T.H. Morrison), cmurray@pices.int (C.C. Murray), deb.wojcik@duke.edu (D. Wojcik).

http://dx.doi.org/10.1016/j.eiar.2016.06.008
0195-9255/Published by Elsevier Inc.

ecosystems—are increasing, in tandem with their potentially overlapping effects on ecosystems (Halpern et al. 2015). Cumulative effects can be produced in numerous ways: by a single activity repeatedly producing a single stressor, a single activity producing multiple stressors, multiple activities producing a single stressor, or multiple activities producing multiple stressors (Fig. 1a) (Clarke Murray et al. 2014). The cumulative effects of overlapping stressors are of concern because effects can interact in multiple ways, including additively (total impact = sum of all impacts), synergistically (total impact > sum of all impacts), or antagonistically (total impact < sum of all impacts) (Crain et al. 2008, Darling and Cote 2008). In addition, the cumulative effect of multiple stressors on coastal and marine systems can have sudden, unanticipated effects, such as driving systems across ecological thresholds—large, sometimes abrupt changes in a system that are caused by relatively small shifts in human pressures or environmental conditions (Huggett 2005, Suding and Hobbs 2009).

Cumulative effects analysis (CEA), sometimes referred to as cumulative impact assessment, could be a powerful tool to manage and reduce the cumulative effects of human activities on ecosystems if improvements are made to the current state of practice (Duinker et al. 2013). Previous research has identified the implementation challenges of CEA (scale - Therivel and Ross 2007, impacts - Canter and Ross 2010, significance - Schultz 2010, baseline - Prahler et al. 2014) and highlighted the need for legal, scientific, and practical advances. While the concepts of cumulative impacts are well described in the scientific literature and are often defined in legal requirements (Table 1), they are not consistently applied in practice (Cooper and Sheate 2002, Ma et al. 2009a). In addition, much of the cumulative effects science that shows how multiple stressors accumulate in the environment (Adams 2005, Crain et al. 2008, Martone and Wasson 2008, Thrush et al. 2008, Coll et al. 2012), where overlapping stressors occur (Halpern et al. 2008, Selkoe et al. 2009, Ban et al. 2010, Clarke Murray et al. 2015), and the effects of multiple stressors (Stelzenmuller et al. 2010, Yang et al. 2010, Kaplan et al. 2012) is not translated into practical and accessible guidance that the community of professionals conducting CEA can use.

Despite calls for changes to CEA (e.g., Peterson et al. 1987, Contant and Wiggins 1991, Duinker and Greig 2006, Masden et al. 2010, Seitz et al. 2011), there have been few improvements and most CEA do not adequately capture potential cumulative effects (Cooper and Sheate 2002, Smith 2006, Duinker et al. 2013, OAGBC 2015). To improve the accounting of cumulative effects, we need to know how practitioners conduct CEA, and specifically how they assess and define impacts, baseline, scale, and significance (Fig. 1b). Evaluating the state of CEA practice is critical for determining how to address the key implementation challenges and for aligning implementation with the best available science.

We undertook a comparative case analysis in four regions around the Pacific Rim: California, USA (CA); British Columbia, Canada (BC); Queensland, Australia (QLD); and New Zealand (NZ) to determine how practitioners currently conduct CEA and how the practice reflects current scientific recommendations. We were interested in determining if there was a relationship between the types of impacts a practitioner included in their CEA (e.g., impacts from similar projects only, similar impacts only, impacts to ecological components only) and how baseline, scale, and significance were determined, and if practice varied based on practitioner geography, role, and experience. We present results of the comparative case study that examine key gaps in and relationships between impacts, baseline, scale and significance in CEA, specifically identifying broad-scale patterns in CEA practices, places where practice and science are aligned, and opportunities to improve CEA efficacy across geographies.

## 2. Methods

Our project investigated how CEA practitioners from four geographies around the Pacific Rim (California, USA (CA); British Columbia, Canada (BC); Queensland, Australia (QLD); and New Zealand (NZ) tackle four primary challenges of CEA: (1) scoping impact metrics; (2) identifying baselines; (3) defining the spatial (geographic area of analysis) and temporal (time frame of analysis) scales; and (4) determining significance. These four geographies were chosen because their respective jurisdictions have legal mandates requiring cumulative effects to be assessed as part of the environmental review process. We chose this level of analysis because this is the level at which CEA is practiced. California, Queensland, and British Columbia have state/province-level mandates for CEA that are more detailed than national mandates or guidance, while New Zealand has a national mandate for CEA. There are specific differences between the mandates each of these geographies uses, but the general framework for all of them is similar enough that assessment methods are comparable across geographies.

To assess CEA methods, we first reviewed completed CEAs to determine the methods and tools practitioners use to address these issues. In most cases, however, there was not enough detail in the analysis to gather this information. To overcome this, we designed a survey consisting of forty questions, including 33 multiple-choice and seven open-ended questions (Appendix 1). The survey included questions about respondent demographics (e.g., position as agency staff or consultant), the legal basis for CEA, information used for assessment, perceived challenges to conducting CEA, and opportunities for improving CEA. The bulk of the survey focused on understanding the types of information used for assessment, particularly for defining impact, identifying baselines, defining spatial and temporal scale, and

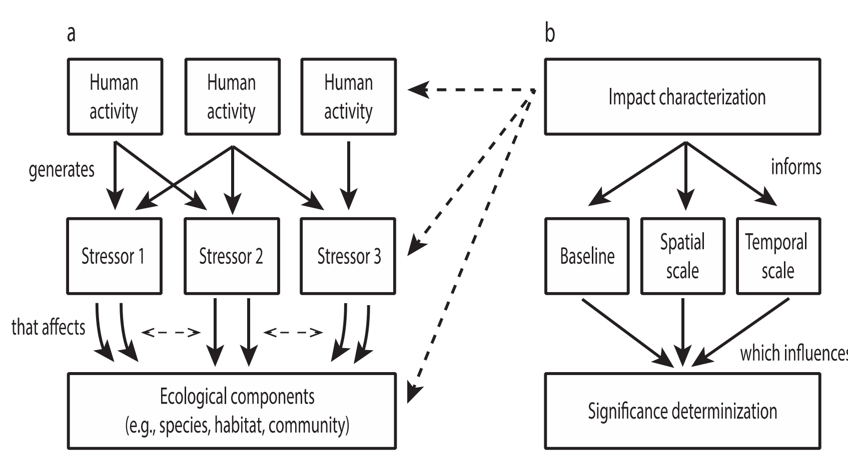


**Fig. 1.** (a) Relationship between activities, stressors, and ecological components, illustrating how cumulative effects are generated via multiple stressors from multiple activities, including the potential for interactive effects (dashed lines between effects arrows); (b) relationship between how impacts are characterized (by activity, by stressor, and/or by ecological components – dashed lines) and baseline selection, spatial scale, temporal scale, and determination of significance. Fig. 1a modified from Clarke Murray et al. (2014).

Please cite this article as: Foley, M.M., et al., The challenges and opportunities in cumulative effects assessment, Environ Impact Asses Rev (2016), http://dx.doi.org/10.1016/j.eiar.2016.06.008