1. Introduction: Foundations, issues and contemporary challenges in cumulative impact assessment

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INTRODUCTION

This *Handbook* addresses cumulative impact assessment and management, also known as cumulative effects assessment (CEA), as conceptualized and practiced in the field of environmental impact assessment (EIA). This book was written by expert researchers, consultants, and advocates deeply engaged in the science, regulations, laws, models, processes, debates, and partnerships of cumulative impact assessment and management. It provides critical information about the state-of-the-art in the research and thinking in the field and offers relevant ideas and approaches to help ensure the success and advancement of CEA initiatives. The *Handbook* is designed to appeal to an international audience of government, Indigenous, industry, and community leaders, as well as to anyone interested in studying CEA at an advanced level. The goal is to raise awareness of innovative concepts, tools, and approaches, thereby promoting best practice development and increasing the efficacy of CEA everywhere.

This chapter sets the context for, and introduces, the remainder of this book. It begins by defining cumulative effects and the need to assess and manage them, exploring important foundational concepts in CEA, and briefly outlining some of the contemporary challenges facing CEA practitioners. After this background is provided, the structure of the book is introduced. This *Handbook* is published in the international series of *Research Handbooks on Impact Assessment*, edited by Frank Vanclay. It features content contributed by dozens of authors from nine countries around the world, representing diverse perspectives from more than 40 organizations. The *Handbook* is divided into four parts: Part I ‘Foundations and Development’; Part II ‘Approaches and Tools’; Part III ‘Cumulative Impact Assessment in Practice’; and Part IV ‘Cumulative Impact Management’. The contents of each part of the book are detailed toward the end of this introductory chapter.

CUMULATIVE EFFECTS AND THE NEED TO ASSESS AND MANAGE THEM

Cumulative effects represent some the most complex and urgent environmental, social, technical, and governance issues of today. Evidence appears in many streams of discourse globally, including within policy, industry, and science circles, public debates, and through art installations. As industry sectors, urban settlements, and related new development projects continue to grow, their impacts collide more often. A recently released government study of the cumulative impacts of a proposed wind farm planned for the waters off Martha’s Vineyard

in Massachusetts, USA, warned of a crowded development space consisting of a dozen more wind farms from the Carolinas to Maine. The project, when combined with a larger build out of thousands of wind turbines off the east coast, is predicted to have major impacts on the commercial fishing industry including increased navigational hazards, lost fishing ground, and lost fishing gear activity causing lost revenue (Harrington, 2020). The impacts on shipping industries will also be significant through increased risk of vessel allision and collision (Harrington, 2020).

Cumulative effects are at the heart of complex scientific debates, including challenges related to water regulation and management in Australia (Swain et al., 2020). Fracking activities at two exploratory sandstone gas wells near existing coal mining sites in a previously untapped thermal coal basin could modify aquifer properties in the Galilee basin in the western Queensland region. A federal government bioregional assessment found that previous modelling assumptions are wrong and that cumulative impacts on water resources would likely be more significant than individual miners had factored into their own modelling (Smee, 2019). Nearby, Butler et al. (2015) found that the cumulative impacts of terrestrial runoff and repeated flooding between 2010 and 2013 resulted in an approximately 56 per cent decrease in coral abundance at the reefs at Hervey Bay in Queensland, but that a lack of local scale monitoring confounds scientists' ability to understand flood plume conditions and their ecological effects.

Cumulative effects are now firmly registered in the public eye. Globally, there is more attention and concern than ever related to cumulative environmental effects issues, such as climate change; freshwater shortages; loss of topsoil and conversion of arable land; air, water and noise pollution; loss of wildlife habitat and the unprecedented decline of biodiversity. Regionally, the ongoing and new development of mining programs, energy and industrial complexes, road building projects, agriculture and drainage projects, and so on, often have cumulative social and cultural impacts that are experienced not just at present, but over multiple generations. The localized effects of projects are highly context specific. Yet, common cumulative social and cultural impacts such as degraded experiences aesthetically; lack of access to traditional lands; compromised flavours, textures and availability of country foods; changes to water quality and quantity; strained medical and other community services; and frayed social fabrics due to temporary worker migration all emanate from such projects. The Organisation for Economic Co-operation and Development (OCED) (2020) notes that spatial planning is a domain in which tensions between economic and environmental objectives have become particularly acute and are expected to escalate as demand for housing, energy, food, fibre, and ecosystem services continues to grow in step with rising global population.

A recent exhibition entitled 'The Anthropocene Project' – a multi-disciplinary body of work combining art, film, virtual reality, augmented reality, and scientific research – brought images into the public conscience that capture the stark reality of many common cumulative effects phenomena caused by intensive urban settlement and industrial development. One of the key messages emanating from the exhibition's documentation of the irreversible marks of humanity is that the pace and scale of emergent cumulative effects issues in the Anthropocene era disproportionately affect communities, particularly the marginalized, the disempowered, and the world's Indigenous peoples. Suliman et al. (2019) speak about Indigenous (im)mobilities in the Anthropocene, and how political action outside formal governance spaces and processes has been critical to the Pacific Islands people to challenge the subordination and marginalization of their role in driving the global climate agenda. In the Anthropocene era,

people, economic activity, and environmental amenities are unevenly distributed across space, and this also holds true for the majority of environmental externalities (OECD, 2020).

Already knowing this to be true, public interest groups in the United States lobbied the federal government in the mid-twentieth century to respond to growing international pressure to safeguard the environment (Weston, 1997). In 1969, the world's first EIA legislation was introduced via the *National Environmental Policy Act*, and by the early 1980s the practice of CEA and management was formalized (Irving & Bain, 1993). The goal of EIA, and relatedly CEA, was to minimize harm to the environment by estimating the environmental impacts of proposed policies, plans, programs, and projects, and then proposing management strategies to avoid, reduce, or mitigate them. CEA is now practiced all around the world, often as an integral component of project-based EIA, but arguably today there is a greater imperative than ever to get EIA and CEA right.

Flawed CEAs are increasingly in the news and are the basis of legal battles often pitting developers against local communities, non-government organizations, and other interest groups. Early in 2020, environmental law charity Ecojustice took legal action against the Canadian federal government on behalf of Ecology Action Centre, Sierra Club Canada Foundation, and World Wildlife Fund–Canada for failing to properly assess cumulative effects in its first regulatory-driven regional-scale environmental assessment (RA) of exploratory drilling for oil and gas off the coast of Newfoundland and Labrador. Ecojustice contends that the flawed RA, conducted under Canada's new *Impact Assessment Act 2019* (IAA; Government of Canada, 2019), was used in combination with a loophole in the IAA legislation to exempt all future offshore exploratory drilling in the region, a region that has already been subject to drilling activity for decades. Any increases in exploratory drilling in these offshore waters threaten important marine ecosystems while also impeding Canada's ability to reach net-zero greenhouse gas emissions by 2050 (WWF, 2020).

There is widespread recognition that we must avoid surpassing ecological limits and critical 'tipping point' situations (Brook et al., 2013) that lead to regime shifts when 'the forces that create stability are overcome by the forces that create instability ... and the global ecosystem tips into disequilibrium' (Cairns Jr., 2004, p. 1). In 2009, the Stockholm Resilience Centre drew up a list of nine planetary boundaries that it would be dangerous to cross. Two of the seven boundaries that have been assessed are already considered 'beyond the zone of uncertainty (high risk)': bio-geochemical flows (phosphorous and nitrogen); and biosphere integrity (genetic diversity) (Steffen et al., 2015). There is convincing scientific evidence that human drivers can cause regime shifts at local and regional scales in the terrestrial biosphere (Brook et al., 2013) – drivers such as the industrial and urban developments that are the subjects of EIA and CEA. These drivers are directly connected with land-use change which could pass 'a planetary tipping point that would induce a potentially irreversible global regime shift for terrestrial biodiversity' (Brook et al., 2013, p. 396).

CEA is a critical tool in the EIA toolkit as it evolves in the twenty-first century. Improvements to many aspects of our lives and environment will require sustained and coordinated effort due to the complex and interrelated nature of many cumulative effects issues and the fact that ecosystem management is a 'wicked problem' (DeFries & Nagendra, 2017). Modern approaches to ecosystem management and, by proxy, cumulative effects issues within ecosystems, will include 'multi-sector decision-making, institutions that enable management to span across administrative boundaries, adaptive management, and collaborative processes to engage diverse stakeholders and address inequalities' (DeFries & Nagendra, 2017, p. 265).

Cumulative effects assessment and management, as a globally relevant practice, is uniquely positioned to tackle wicked problems in that it was created to address the combined impacts of past, present, and future human activities and natural processes.

FOUNDATIONAL CONCEPTS IN CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT

In an international scan of terminology and definitions, Gunn and Noble (2014) found that the terms ‘cumulative effect’ and ‘cumulative impact’ are often used interchangeably. As such, this volume does not substantively differentiate between ‘effect’ and ‘impact’, and authors throughout the *Handbook* use both terms. The editors acknowledge that effects and impacts *de facto* are distinct, and that the act of determining whether an impact has occurred following some measurable effect is a subjective exercise that reflects the values of those making the assessment. In other words, an effect is not necessarily regarded as an impact if it does not affect a component of the environment in any significant or substantial way, as deemed by society. In a project-based EIA context, determining the significance of residual cumulative effects (having taken into account proposed mitigation measures) gives an estimation of the nature and severity of anticipated impacts of predicted changes to the environment. That said, it is far more important from a scientific and management perspective to focus on understanding cumulative change – and when that change is significant (for example, crosses a limit or boundary) – than it is to distinguish between an ‘effect’ and an ‘impact’.

Definitions for the terms cumulative ‘effect’ and cumulative ‘impact’ are many and varied. The United States Council on Environmental Quality (US CEQ) (1997), which originally clarified the definition of cumulative impacts after they were alluded to in the National Environmental Policy Act (NEPA) (Irving & Bain, 1993), describes them as:

- the total effect, including direct and indirect, on a given resource, ecosystem, or human community of all actions taken;
- effects that may result from the accumulation of similar effects or the synergistic interaction of different effects;
- effects that may last for many years beyond the life of the action that caused them;
- effects that must be analysed in terms of the specific resource, ecosystem, or human community affected, and not from the perspective of the specific action that may cause them; and
- effects that must be approached from the perspective of carrying capacity, thresholds, and total sustainable effects levels.

The European Commission defines ‘cumulative impacts’ as impacts that result from incremental changes caused by other past, present, or reasonably foreseeable actions together with the project (Hyder, 1999). More recent definitions of ‘cumulative effect’ such as the one endorsed by the Canadian Council of Ministers of the Environment (Gunn & Noble, 2014) also capture natural phenomena: ‘a change in the environmental caused by multiple interactions among human activities and natural processes that accumulate across space and time’. There are numerous kinds of cumulative effects including additive, interactive, synergistic, antagonistic, and so on. Table 1.1 presents 40 types of cumulative effects that have been discussed in EIA literature since the introduction of NEPA, though this is not necessarily an exhaustive list.

Table 1.1 Types of cumulative effects

Additive	Complex causation	Fragmentation	Interrelated	Secondary
Aggregative	Compounding	Growth-induced	Linear	Sequential
Ameliorative	Countervailing	In-combination	Masking	Space-lags
Amplifying	Crescive	Incremental	Multiplicative	Space-crowded
Antagonistic	Cross-boundary	Indirect	Neutralizing	Structural surprise
Collective	Cross-media	Induced	Nibbling	Synergistic
Combined	Discontinuous	Integrative	Offsite	Time-crowded
Compensatory	Exponential	Interactive	Residual	Time-delayed

The actions that cause cumulative effects are often varied (heterotypic) in nature, but also can be identical (homotypic) actions. For example, activities associated with forest harvesting such as road building, stream crossings, and clearing native vegetation in cut blocks together can degrade wildlife habitat for fur-bearers such as gray wolf (Houle et al., 2009), but repetitive, episodic discharges of pulp mill effluent into a river can also degrade water quality for salmon and other freshwater biota (Marmorek et al., 1992). In both cases, the perturbations can overwhelm the ability of the receiving environment to absorb the change, causing a cumulative environmental effect.

Cumulative effects typically manifest or ‘accumulate’ in gradual, piecemeal fashion, which makes them difficult to detect. Cumulative effects have been described as ‘progressive nibbling’, ‘death by a thousand cuts’, and the ‘tyranny of small decisions’:

‘Progressive nibbling’ refers to the often-insidious process of land conversion and/or environmental degradation that occurs slowly over time and typically in the absence of a regional perspective on development. ‘Death by a thousand cuts’ refers to the phenomenon whereby small, but repetitive, insults to the same environmental component occur over and over and eventually, but often unexpectedly, cause its ‘death’ or total demise. The ‘tyranny of small decisions’, a concept originally introduced by economist Alfred Kahn in the 1960s, helps explain how both of these phenomena can occur simultaneously: it is a situation in which a number of separate decisions cumulatively, and often unintentionally, result in a condition that is neither optimal nor desirable. (Noble & Gunn, 2013)

Thus, cumulative effects are often insidious: while many development activities and decisions can be individually insignificant, together their impacts can have regional and even global repercussions. William Odum (1982, p. 728) explained how such seemingly ‘small decisions’ can result in significant adverse environmental outcomes, and the danger of ignoring the collective power of those decisions:

Consider, for example, the loss of coastal wetlands on the east coast of the United States between 1950 and 1970. No one purposely planned to destroy almost 50% of the existing marshland along the coasts of Connecticut and Massachusetts ... However, through hundreds of little decisions and the conversion of hundreds of small tracts of marshland, a major decision in favour of extensive wetlands conversion was made without ever addressing the issue directly.

CEA, as a tool, is meant to help decision-makers identify and avoid an entire suite of environmental effects – *in addition to those most direct, immediate, and easily detected*, which are typically the subject of project-based EIA. It is also variously defined across jurisdictions, but in general CEA consists of a systematic process to identify significant impacts that could result from interactions between projects; interactions that might not be apparent from project specific environmental impact statements (European Commission, 1999), whether biophysical

or sociocultural. There are numerous guidance documents and academic papers that describe the steps involved in CEA practice (for example, see Ross, 1998; European Commission, 1999; Hegmann et al., 1999; Duinker & Greig, 2006; Canter & Ross, 2010; Noble, 2020), but in essence it consists of four basic phases (Gunn & Noble, 2012):

1. A scoping process to identify cumulative effects of the project on valued components (biophysical and sociocultural);
2. A 'retrospective' analysis phase to establish the current baseline, assess the historical condition of valued components and characterize trends and changes in conditions over time;
3. A 'prospective' analysis phase to connect the project and other actions in the region to the valued components and predict how valued components, via indicators, may respond to additional stress or disturbance in the future; and
4. A significance determination to evaluate the importance of the cumulative effects of the project on valued components when considering the total effects on those valued components. This determination is subject to understanding how much more change in the condition of a valued component is tolerable. It requires evaluation of the cumulative impact in light of ecological limits, boundaries, and/or management targets, if available. The impact of the project must not be compared to the impact of other projects, but rather considered 'in addition to' the impacts of other projects.

Mitigation and management, including follow-up, are critical aspects of CEA in line with established EIA best practice. Cumulative effects management involves the identification and implementation of measures to control, minimize, or prevent their adverse consequences (CCME, 2014). A management plan ideally considers ecological boundaries, establishes management targets and response triggers, takes an adaptive management approach, engages affected interests in management programs and activities, and clearly defines roles and responsibilities for implementation, monitoring, and feedback over the long-term. The gravitas of assessing and managing cumulative effects in EIA cannot be understated as 'each additional disturbance or impact, regardless of its magnitude, can represent a high marginal cost to the environment' (Gunn & Noble, 2012, p. 6). The following two examples demonstrate this concept, and what can happen when cumulative effects are not properly addressed:

- In southwest Saskatchewan, Canada, a 1940 km² ecologically rich land base consisting of active sand dunes, rare and endangered wildlife and bird species, and plants of Indigenous cultural importance, is subject to the pressures of approximately 1500 natural gas wells, cattle grazing, and more than 3000 km of access roads and trails. The landscape is now significantly fragmented, and biodiversity in a once native grassland ecosystem is at risk. Of the 1500 wells in the area, only five proposals were subject to an EIA, none of which concluded there were significant environmental effects (GSH SAC, 2007). Any further development in this region is superimposed upon an already highly disturbed landscape, making the additional impacts of any new projects potentially highly significant.
- The Athabasca River basin in Alberta, Canada, is exposed to a wide range of land-use activities including agriculture, forestry, pulp and paper operations, and petroleum extraction. Forests have been fragmented by roads, power lines, pipelines and other disturbances, and the amount of old growth forest has been significantly reduced (Schneider, 2002). Between 1966 to 1976 and 1996 to 2006, the number of pulp mills discharging into the Athabasca basin increased from one to five; total farm area increased from 47.2 million

acres to 52.1 million acres; the number of operating oil sands leases increased from two to 3360; water withdrawals increased from approximately 12 million m³ per year to 595 million m³ per year, of which more than 70 per cent can be attributed to oil sands operations. Between these two time periods the cumulative annual flow in the Athabasca River decreased by more than 500 m³ per second, and temperature increased by 1.4°C; conductivity, turbidity, and phosphorous levels also increased (Squires et al., 2010). None of the actions identified above, including those subjected to EIA, were deemed to have a significant cumulative environmental effect on the Athabasca River. Yet, ‘the rapid pace of industrial development and corresponding growth in water demand from the Athabasca River, especially when considered cumulatively with climate change, necessitate immediate action to protect its vulnerable aquatic ecosystems by limiting withdrawals to within sustainable levels’ (Swainson, 2009, p. 17). The United Nations World Heritage Committee, at the urging of local Indigenous groups, intervened in 2015 and 2017 to request strategic environmental assessment of the cumulative effects to the Wood Buffalo National Park, which encompasses the Athabasca River Delta (Parks Canada, 2020).

Without CEA, EIA misses the point: the need to recognize and prevent irreversible and undesirable environmental effects (Gunn & Noble, 2012), and, ideally, to facilitate positive ones. It is widely understood that cumulative effects are the only effects that really matter (Ross, 1994), and that CEA is EIA ‘done right’ (Duinker, 1994).

CONTEMPORARY CHALLENGES IN CUMULATIVE EFFECTS ASSESSMENT AND MANAGEMENT

By the mid-1980s, there was rising concern among the members of the Canadian Environmental Assessment Research Council (CEARC) and the United States National Research Council (NRC) that ‘neither scientists, nor institutions work at the temporal and spatial scales needed for the assessment of cumulative effects’ (Government of Canada, Minister of Supply and Services, 1985, p. ix). Several shortcomings of EIA focused on specific projects were noted:

- It ignores the additive effects of repeated developments in the same ecological system, e.g., the effects of the loss of wetlands and disposal of toxic chemicals on fish habitats and productivity;
- It does not deal adequately with precedent-setting developments that stimulate other activities, especially in fragile environments;
- It ignores changes in the behavior of ecological systems in response to increasing level of perturbation, e.g. nonlinear functional relationships;
- It does not encourage the development of comprehensive environmental objectives that reflect the broad goals of society. (Ibid.)

Concerns like these led to the emergence of strategic environmental assessment (SEA) and to a greater emphasis on RA, both of which are better positioned to proactively and more comprehensively address cumulative effects issues. Part of the challenge throughout the history of CEA, whether performed as part of project-based EIA, SEA, or an RA exercise, is the often amorphous nature of cumulative effects issues themselves, which tend to have diffuse sources, arise from the ‘nibbling’, incremental changes that are hard to notice until they are grand in scale, and involve many projects not subject to any impact assessment process. Table 1.2 sum-

Table 1.2 Types of cumulative effects

Air/Atmosphere	Water	Land
<ul style="list-style-type: none"> • Acid rain • Air pollution • Climate change • Global warming (greenhouse gas emissions) • Light pollution • Noise pollution • Volatile organic compounds (VOCs), PM10, and other emissions 	<ul style="list-style-type: none"> • Freshwater shortage • Freshwater pollution • Polar ice sheet melt • Plastics in oceans • Ocean acidification • Water insecurity • Acidification 	<ul style="list-style-type: none"> • Land-use change/conversion • Urban sprawl • Topsoil loss/erosion • Soil pollutants/contaminants
Geological	Community	Biota
<ul style="list-style-type: none"> • Mineral depletion • Nutrient depletion • Structural collapse 	<ul style="list-style-type: none"> • Social disruption, displacement • Loss of social capital, cohesion • Cultural erosion, language loss • Heritage loss • Inequality (income, gender, etc.) • Disease and health impacts 	<ul style="list-style-type: none"> • Biodiversity loss (genetic, life forms, functional groups) • Species extirpation/ extinction • Habitat fragmentation • Reduced availability, degradation of habitat • Bioaccumulation • Mortality, population collapse

marizes some of the most prominent cumulative effects issues facing communities and world leaders today, many of which emerge incrementally.

Looking at the issues identified in Table 1.2, two things are clear. First, contributions to cumulative effects issues must be considered in project specific assessments, SEA and RA, but to be maximally effective these processes must also be supported by integrative science, local and Indigenous knowledge, and a strong connection to the wider spheres of planning, policy-making, and the regulatory regime. Second, it is unsurprising that CEA performed as part of project EIA has been fraught with enduring challenges given the magnitude and complexity of these issues. This has been chronicled in many practice reviews over the years (Canter & Ross, 2010; Parkins, 2011; Ma et al., 2012; Bailey et al., 2014; Noble, 2015; Foley et al., 2017; Willsted et al., 2018). Rather than review the range of technical, procedural, transactive, and conceptual challenges already aptly pointed out by others – many of which are the same types of challenges that confront all forms of EIA worldwide – it is worth noting some of the additional contemporary challenges that CEA practitioners face in the twenty-first century.

To begin with, the manner in which valued components are selected for CEA, when CEA is practiced as a component of project EIA, needs some reconsideration. Olagunju and Gunn (2013) found there is heavy reliance on the ‘residual effects analysis’ method when identifying which valued components to include in CEA. In other words, only those valued components deemed to still be at risk of significant impact after mitigation measures are applied are retained for further analysis in a CEA. Valued components predicted to experience minor or moderate impacts are typically not subject to mitigation measures, nor are they considered with respect to potential cumulative effects resulting from interaction of the project with other projects and drivers of change in the area. This means that potentially significant cumulative effect interactions are overlooked in project EIA, because it is the total effect on valued components that is important. For example, if a hydro-electric powerline corridor project is predicted to have a minor impact on a wolf range, it likely will not be considered in a CEA. However, if

that range is already intersected by many other linear features such as highways, pipelines, and existing powerline corridors, as was the case for the proposed Bipole III transmission line in northern Manitoba (see Gunn & Noble, 2012) then the ‘minor’ impact caused by the additional powerline corridor could in fact be very significant from a cumulative effects perspective. As noted above, even minor and moderate effects of a project can be very significant to the sustainability of a valued component if it is already in a compromised state. In general, the process of valued component selection for CEA can be a ‘black box’ (Olagunju & Gunn, 2013) and ‘not necessarily transparent to all stakeholders and rights holders about how a certain valued component got included in the process’ (K. Banister, personal communication, June 19, 2020).

Valued component selection must also become more balanced in the twenty-first century. In practice, biophysical cumulative effects have tended to receive far more attention in CEA than sociocultural effects, as have adverse effects rather than positive effects. Given the technical, political, and legal savvy of non-government organizations and Indigenous groups, the connectedness of individuals through social media and the now mainstream sustainability and climate agendas, the cumulative social and cultural impacts of development can no longer be shunted aside. Thus, there is a real need to define and build up this area of practice in CEA worldwide, especially at the intersection of community, environment, and health (Halseth et al., 2016). Work has begun to identify useful social indicators for CEA (population growth rate, educational attainment, self-assessed quality of life, equity [that is, distribution of benefits], and locus of control) (Mitchell & Parkins, 2011), but social indices arguably must go further to measure food security, water security, and other aspects of individual and population health for different kinds of communities and regions.

A better understanding of cumulative impacts on communities will hinge, in part, on transforming the ways in which communities are consulted. Early engagement and continual communication with affected interests have long been considered essential to good practice in both EIA and CEA, but cumulative effects can be hard to visualize. The means by which impacts are communicated need to shift from paper to screens and become far more conversational (rather than adversarial) and interactive, and therein lies the challenge – both technical and financial. CEAs can be greatly enhanced in the years ahead through increased use of remote sensing and drone technology. For example, LiDAR (Light Detection and Ranging) is used in pollution modelling to detect particles of carbon dioxide, sulphur dioxide, and methane, and to create pollution density maps. Drones allow image and video capture of unstable, inaccessible, and dangerous areas that were previously much more difficult and often very expensive. They are now used to track and count wildlife, improve monitoring of endangered species, and assess land-use change, and can be used in myriad other ways to assess cumulative effects. The amount of data that can be collected in a short period has increased dramatically. Tangentially, infographics and other means of visual communication also hold great promise as ways to improve the effectiveness of discussions about cumulative effects. Visual communication is more flexible and often more impactful than verbal communication and is able to reach both a broader and a younger audience. Interactive mapping apps, simulations, quick polls, conversation forums, and ‘Twitter storms’, among other means of digital engagement, are transforming the way the public is consulted (Sinclair, 2020). In the future these will complement, if not totally replace traditional in-person forums.

More effective CEA will also hinge in part on transforming the way in which impact significance is communicated by proponents and considered in project approvals processes. Although it is clearly acknowledged that ‘determinations of significance depend on the

subjective informed judgment of decision-makers concerning the valued component being considered' (Ehrlich & Ross, 2015, p. 88), and the standard significance spectrum is used successfully by different cultures, GBA+ (Gender Based Analysis +) in EIA and CEA is new in Canada (and likely many other countries). There is work to be done to more deeply explore social justice issues and acknowledge the disproportionate impact that development has on diverse groups, including those identifiable by sex and gender; age; place of residence; ethnicity; socioeconomic status; employment status; or disability (Government of Canada, 2020). For example, 'research on the gendered aspects of climate change mitigation and adaptation in developed countries is scant, even more so in Canada' (Rochette, 2016, p. 383). Relatedly, CEA also needs to better address both inter- and intra-generational equity (that is, how impacts are disproportionately experienced between groups of the same generation and across different generations). Equity determination is among the key components of any sustainability-focused assessment (Gibson, 2006; Morrison-Saunders et al., 2015), and yet typically ignored when communicating project impacts (Jamal, 2019).

The cumulative impacts of development are often experienced more severely by the world's Indigenous people (United Nations Department of Economic and Social Affairs, Indigenous Peoples, 2020a), including communities vulnerable to climate change (Tsosie, 2007). Steps are being taken on an international scale to change that. Introduced in 2007, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) has been adopted by 148 countries including Canada, the United States, Australia, and New Zealand. It 'establishes a universal framework of minimum standards for survival, dignity and well-being of the Indigenous peoples of the world' (United Nations Department of Economic and Social Affairs, Indigenous Peoples, 2020b). For this reason, respect for and integration of Indigenous knowledge, interests, and rights in EIA and CEA processes is key to the increased efficacy of both practices in the future. However, true understanding of the significance of cumulative impacts on Indigenous people requires a nuanced approach that challenges the rational-scientific foundations of impact assessment and western science. Wheatley (1998, p. 537) explains:

Environmental change, often the result of Western industrial development, has had major impact on Canadian Aboriginal people. Even when there are no provable direct health effects, Aboriginal people's holistic concepts of health, balance, and harmony, and the interrelatedness of health and environment lead them to regard social and cultural effects as health effects ... [F]actors such as Aboriginal holistic concepts of environment and health, perceptions of risk, and difficulties in communication contribute to these social and cultural effects and their subsequent health effects – effects which frequently present a greater problem in Canadian Aboriginal communities than do the direct health effects of environmental change.

The intersection of the global climate crisis and the obligation to fulfill Indigenous peoples' rights to land, territories and resources creates a backdrop that renders CEA in the 21st century more challenging than ever before. Arguably, the path forward must include long-overdue power shifts and perspective shifts in setting terms of reference for CEA and selecting decision-making models. Power and perspective shifts need also apply to the relationship between western science and Indigenous knowledge (IK) in both project-based EIA and CEA. In studying the cumulative impacts of a 60-year-plus program of hydro-electric development on Indigenous communities in northern Manitoba, Canada, Craft (2020) observed that, in EIA processes, IK is typically used as a source of data for western science or used as a means to validate western science and its conclusions; the level of influence with regard to

decision-making is still often highly weighted toward western science. Very rarely has IK been the point of departure for western science, and even more rarely has IK formed the process through which decision-making takes place (Craft, 2020). The practice of CEA may be significantly improved through Indigenous-led processes, the use of Impact Benefit Agreements (IBAs), and/or ‘two track’ approaches to impact analysis which feature IK as stand-alone assessments alongside traditional scientific analyses.

In summary, this chapter briefly highlighted some of the contemporary challenges that the CEA community faces and will grapple with well into the future. The urgency to improve CEA as a practice and address the many cumulative effects of issues of concern to society is intensifying in light of extreme and unexpected natural disasters. Events such as the extensive Australian bushfires, fires burning in the Amazon forest long after the dry season and massive algal blooms in Antarctica further complicate environmental management and sustainability planning, stretching limited resources and adding to the pressure of mitigating the already widespread impacts of urban and industrial development. Our collective struggle toward better CEA and more efficacious EIA can be assuaged by continuing to share best practices from around the world with one another, and that is what this *Handbook* strives to do. The structure and contents of the rest of the *Handbook* are briefly described below.

HANDBOOK STRUCTURE AND CONTENTS

The chapters that follow describe a variety of innovative concepts, case studies, proposed approaches, and reflections from various practitioners and scholars of CEA, each of which is meant to represent the best in the field today and inspire more effective performance of CEA internationally.

Part I: Foundations and Development

The *Handbook* begins with several chapters on the nature of cumulative effects, including how various governments are attempting to address cumulative effects through legislation, regulation and policy, how cumulative effects emerge, and why they are challenging to address in project-based EIA. Following Chapter 1, Chapter 2 presents CEA requirements in selected developed and developing countries. This is a joint effort by Ayodele Olagunju (Canada), Divine Odame Appiah (Ghana), Paulina Maria Porto Silva Cavalcanti (Brazil), Bridget Durning (United Kingdom), Juan Carlos Tejeda-González (Mexico), Jason McLean (Canada), Richard Morgan (New Zealand), and Rebecca Nelson (Australia) to examine policy and regulatory contexts for CEA in their countries. Together, they outline a relatively global picture of progress in CEA, finding that progress varies according to country, and that even in countries with advanced EIA systems, there is difficulty linking legal requirements to practice due to a lack of implementation guidelines. Their chapter concludes by identifying issues that must take centre stage in the effort to strengthen CEA practice internationally.

In Chapter 3, Jeff Olson brilliantly portrays how cumulative effects unintentionally emerge over time and space, placing prairie farmland drainage and the phenomenon of wetland loss in east-central Saskatchewan at the crux of his first-hand account. He describes how farmers, seeking to improve their own lands, have incrementally drained huge numbers of wetlands causing serious impacts to wildlife habitat, flooding, and massive increases to the affected

watersheds' effective drainage areas. Central to his story is the provincial government's administrative and policy landscape, which has been largely ineffective in identifying, preventing, and mitigating cumulative impacts to wetlands over the past century. The dynamics in this story represent the dynamics of so many other cumulative effects issues that have emerged in the twentieth and twenty-first centuries elsewhere in the world. It is a cautionary tale about the critical need for a regional view of impacts, long-range assessments and planning, and creative and coordinated interventions between private landowners, industry and government.

In Chapter 4, George Hegmann, one of the world's most experienced and influential CEA practitioners, explains the contemporary challenges of CEA at the project level. He also tells a story about what it is like for CEA practitioners to deliver on a highly complex set of tasks while meeting regulatory requirements on short timelines with limited budgets. He explains that CEA currently lives in two worlds that barely talk to each other. In one world are practitioners embroiled in regulatory EIA. The other world is occupied by researchers of ecosystems and assessment process and method, peering into the other world, and getting frustrated by what they see. His goal is to amplify the practitioner's perspective, as it is rarely heard or fully understood, and encourage 'bridge building' between these two worlds.

Part II: Approaches and Tools

Part II of the *Handbook* details a variety of inventive approaches to CEA and tools that have proven useful to CEA practitioners. This includes chapters on scenario planning, forecasting, using ecological thresholds, and taking a systems approach to CEA, among other topics. In Chapter 5, Ilse Aucamp and Stephan Woodborne help the reader to conceptualize cumulative social impacts in complex development requirements, particularly the relationship between development, livelihoods, well-being, and ecosystem services. They introduce a conceptual model with four 'zones' that are critical to appreciating the varied nature of cumulative impacts, illustrated with an example of a town in South Africa called Lephalale that has undergone massive development following large industries moving into the region. They explain why the primarily negative consequences of development near Lephalale can be attributed to the failure to consider the cumulative dimensions of impacts on a strategic level, especially from a social perspective, and urge practitioners to adopt a regional scale of assessment.

Peter Duinker and Lorne Greg examine the critical role of scenario planning in CEA in Chapter 6. They argue that the temporal domain of crucial significance in CEA is the future, and because there is no empirical record of the future, it is necessary to develop a small suite of reasonably plausible narratives of future development and activity patterns as a foundation for CEA. They describe four cases that illustrate the feasibility of scenario planning in CEA and the value of information gained as a result. One of most important lessons emerging from these cases is that what a valued component can tolerate is entirely context dependent. Scenario analysis is the tool that allows us to imagine different outcomes associated with different drivers of change, and this is ultimately critical to charting a desired path forward.

In Chapter 7, Chris Sunderland shares with readers a conceptual framework for forecasting in CEA that he derived based on project experience gained over the course of his long consulting career in many countries around the world. In his chapter, he lays the groundwork required to forecast cumulative effects effectively. In his framework, he touches on: requirements for designing the CEA – foundational considerations for forecasting (related to baseline studies and longitudinal data, resiliency of valued components, context of the receiving environment,

data availability, and scale); methodological considerations for forecasting; and the need to determine who is responsible for the forecasted cumulative effects. He illustrates this framework with a hypothetical forecasting example, concluding that forecasting in CEA works best when it is based on a collaborative model with multiple perspectives considered and when there is shared responsibility for mitigation and adaptive management strategies.

In Chapter 8, Evan Hamman, Karen Vella, and Umberto Baresi take readers on a journey to the Great Barrier Reef (GBR) World Heritage Area. Their chapter examines government policy related to strategic environmental assessment and CEA in the GBR through the lens of the SEA jointly undertaken by the Queensland and Australian Governments between 2012 and 2014. This SEA, which was requested by World Heritage Convention bodies, is the largest and most comprehensive SEA ever undertaken in Australia, and many lessons regarding CEA were learned. Ultimately, the SEA for the GBR can be credited as one of the key drivers in domestic policy reform with respect to assessing cumulative impacts. It put a spotlight on the historical lack of knowledge about cumulative impact assessment in Australia and became a catalyst for further initiatives, including a formal policy position (the Great Barrier Reef Marine Park Authority, 2018), about how best to manage cumulative threats to the site.

Chris J. Johnson and Justina C. Ray detail the challenges and opportunities of applying ecological thresholds to environmental decision-making in Chapter 9, including within an EIA and CEA context. They focus on ecological thresholds because they are becoming more prominently used in natural resource management and conservation decision-making. That being said, the authors argue that focusing on higher levels of ecological organization across increasing spatiotemporal scales of application (as in CEA) inevitably increases the challenge of considering both ecological and socioeconomic values in an assessment. Johnson and Ray demonstrate that, in reality, there are considerable challenges to identifying both precise and general ecological thresholds. This in turn creates challenges for determining the significance of an environmental impact. To cope with this reality, they discuss the importance of monitoring and learning in order to adjust course on the management of existing projects and the approval of new projects.

In Chapter 10, Jill Blakley and Bram Noble explore the assessment of cumulative effects in a regional and strategic context. They argue that two foundational components comprise good CEA frameworks, namely, accumulated state assessment and strategic assessment. They discuss two possible approaches to accumulated state assessment: (1) an effects-based approach in which involves monitoring indicators of important environmental receptors against established thresholds and limits; and (2) a stressor-based approach which focuses on measuring the accumulation of human disturbance and identifying whether indicators of disturbance are at or below an acceptable level of change relative to a reference condition. They explain that these approaches are sometimes combined with one another, but also, ideally, with a strategic approach to CEA. Noble and Blakley review two case examples to illustrate that an accumulated state assessment combined with a strategic approach to CEA adds to the ability to explore what could be and what should be in terms of desired environmental and sustainability outcomes.

At the close of Part II, Bill Grace and Jenny Pope present their current thinking about how systems modelling can be usefully applied to cumulative social impact assessment. In Chapter 11, Grace and Pope describe a methodology they developed in partnership with industry for cumulative social impact assessment that is grounded in systems analysis. This methodology served as the basis for understanding and managing the potential impacts of liquefied natural

gas (LNG) development in the Kimberly region of Western Australia. Specifically, they focus on community well-being, which they argue is an appropriate goal for social impact assessment and any sustainability-oriented impact assessment, including CEA. Some of the observed benefits of the model are that it aids in the understanding of feedback loops, the identification of critical thresholds and tipping points, and the ability to focus on impacts of central importance in the CEA process.

Part III: Cumulative Impact Assessment in Practice

In Part III, the *Handbook* transitions to a collection of chapters discussing cumulative impact assessment in practice; particularly the lessons learned through CEA applications in different contexts. In Chapter 12, Riki Thérivel, Jill Blakley, and Jo Treweek discuss mitigating cumulative biodiversity impacts. Given the severe loss of biodiversity at all scales over the past century, they argue that biodiversity should be a valued component in all impact assessments and provide an in-depth look at managing the cumulative impacts on biodiversity through each stage of a typical impact assessment process. Their chapter concludes with a case study of successful avoidance of cumulative impacts on a series of nature conservation areas in southern England called the ‘Thames Basin Heaths’.

Then, in Chapter 13, James Baines and Nick Taylor give the reader an in-depth look at a case of windfarm development and cumulative social impact assessment (SIA) in New Zealand. Their chapter probes a central question: while ‘green’ is good, is ‘more green’ always better? They do this by discussing the details of a SIA completed for the Palmerston North City Council and the methodological issues raised by SIA around the use of multiple methods and integration with other assessments. They share many key learnings from this exercise, including the cumulative social effects identified through extensive public consultation. They conclude that there is risk in responding to the well-known cumulative effects in one aspect of energy development (fossil fuel use) of creating cumulative effects in another aspect (wind farming).

In Chapter 14, Sue Vink, Paul Howe, and Chris Moran explore the cumulative effects of groundwater and, in particular, the cumulative impacts of mining on groundwater supplies. They present an original framework for assessing such impacts; a risk-based approach combined with elements of adaptive management. Each methodological component of their framework is carefully detailed, from data gathering through to risk management. The framework they describe has been used, either wholly or in part, in several applications in Australia. They conclude the chapter with a summary of key lessons derived from the most notable of these applications: an assessment of the cumulative impacts of the coal seam gas industry on groundwater in the Surat basin, Queensland, Australia.

In Chapter 15, we turn to Jochen A. G. Jaeger and Aurora Torres to learn about 14 lessons applicable to CEA from the applied discipline of road ecology. Practitioners frequently ask for better methods and tools for CEA. In response, Jaeger and Torres want to improve the effectiveness of CEA in all forms of assessment by identifying aspects of road-related effects that are often overlooked, proposing large-scale approaches to better incorporate road effects in CEA, and suggesting cost-effective mitigating strategies to reduce and mitigate the cumulative effects of road building.

Chris Powter and Dallas Johnson, in Chapter 16, give the reader an insider’s look at how the Alberta provincial government is using an innovative policy and planning approach to address

the cumulative impacts of oil sands extraction activity in the world's third largest oil reserve. In 2007, the government began shifting from a project-by-project environmental assessment system to a cumulative effects management system. Key to the success of this transition has been assessing cumulative impacts on a regional scale. Another key aspect of this approach has been nesting CEA within a comprehensive land-use planning framework for the province, thereby linking assessment outcomes to planning policies and development guidance for specific regions. The Albertan example is a 'master class' in effective tiering which many CEA practitioners will find educational and inspiring.

To close Part III, Barry J. Wilson conceptualizes holistic CEA for watershed risk assessment and provides a recent example of how this model has been applied to assess cumulative watershed risks to clean water connected with a major oil pipeline development (the TransMountain Pipeline) in the North Thompson watershed in western Canada. This is a conceptual model that underpins much of Barry's work as a systems ecologist and CEA consultant. Throughout Chapter 17, Barry urges CEA practitioners not to accept 'business as usual' as the mindset underlying cumulative effects analysis and watershed risk assessments. He argues that CEA innovation can be achieved, in part, by merging ways of knowing; that is, blending Indigenous traditional knowledge with contemporary scientific understandings of nature. Wilson has demonstrated as much in his own practice.

Part IV: Cumulative Impact Management

Finally, Part IV of the *Handbook* addresses cumulative impact management; that is, the process of implementing the results and recommendations emerging from a CEA exercise. In Chapter 18, Richard D. Margerum talks about the limitations of utilizing collaborative governance for cumulative effects assessment and management. This is a chapter of important insights as collaboration is increasingly regarded as a preferred approach to governance rather than a discrete process of planning. Margerum points out that cumulative effects assessment and management often lacks several key attributes necessary for successful collaborative governance, including shared power, joint decision-making, and institutional structures that allow adaptive decision-making. His goal in Chapter 18 is to summarize important factors for assessing the strengths and weaknesses of collaborative governance efforts related to CEA and identifying opportunities for the future.

In Chapter 19, contributed by Will Rifkin, the concept of 'adaptive assessment' is introduced. Rifkin discusses a case in which he applied a form of adaptive assessment to an agricultural region near Brisbane, Australia, to identify cumulative socioeconomic impacts of multiple infrastructure projects for natural gas development. In this chapter, CEA is posited as an iterative process, one to be reconsidered and refined in light of the history of the region and in light of different perspectives and ongoing socioeconomic changes. Rifkin proposes a useful set of heuristics to guide assessment processes as they unfold and are revisited over time. His view is that there is no one 'right way' to conduct CEA; rather, the process of CEA must be adaptive and amenable to assessing impacts throughout the life of a resource development project.

In Chapter 20, daughter and father team Kiri and Lindsay Staples present their understanding of cumulative effects and governance in the Yukon territory in northern Canada. The Yukon provides a unique opportunity to better understand the relationship between Indigenous co-governance and cumulative effects because 11 of the 14 First Nations in the

Yukon have recently signed modern treaties with the Canadian federal government granting them self-governance. In their chapter, they describe how the *Umbrella Final Agreement* lays the groundwork for a co-governance approach to cumulative effects, and they outline lessons emerging from early attempts at implementation.

The final chapter in the *Handbook*, contributed by A. Cole Burton and Cheryl-Lesley B. Chetkiewicz, talks about effective ecological monitoring to address cumulative impacts on biodiversity. This is an appropriate topic on which to end the book, given the increasing pressures that the Earth's ecological systems face in the twenty-first century. In Chapter 21, Burton and Chetkiewicz aim to foster 'monitoring that matters'. Their focus is primarily on ecological monitoring of terrestrial biodiversity, particularly the distribution and abundance of species. They find that while there is a long history of programs for ecological monitoring of cumulative impacts, there is an equally long history of ineffective programs emanating from EIA processes that have not resulted in positive outcomes for biodiversity and related ecosystem services. Part of the path forward toward better monitoring of cumulative impacts will involve: including quantitative experts in ecological monitoring as part of the EIA team; embracing new technologies in environmental sensing; harnessing opportunities for community-based monitoring and citizen science; and taking guidance from emerging global ecological monitoring initiatives, among other priorities.

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