PROFILE

Cumulative Environmental Change: Conceptual Frameworks, Evaluation Approaches, and Institutional Perspectives

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ABSTRACT / Cumulative environmental change or cumulative effects may result from the additive effect of individual actions of the same nature or the interactive effect of multiple actions of a different nature. This article reviews conceptual frameworks of cumulative environmental change and describes analytical and institutional approaches to cumulative effects assessment (CEA). A causal model is a common theoretical construct, although the frameworks vary in their emphasis on different components of the model. Two broad approaches to CEA are distinguished: one scientific and the other planning oriented. These approaches should not be interpreted as competing paradigms but rather different interpretations of the scope of CEA. Each approach can provide a distinct but complementary contribution to the analysis, assessment, and management of cumulative effects. A comparison of the institutional and legislative response to CEA in Canada and the United States shows that Canada is following the American example of incorporating the analysis and assessment of cumulative effects into regulatory actions and administrative procedures that also govern environmental impact assessment.

The phenomenon of cumulative environmental change and its implications for human society are evident throughout history. The decline of ancient civilizations in Mesopotamia is attributed in part to incremental changes in environmental conditions, particularly increases in soil salinity and sedimentation induced by centuries of irrigation. In the plains of North America, the aggregate environmental effects of more than 100 years of cultivation are apparent in gradual reductions in soil fertility. More recently, projected changes in future climate and climatic variability associated with the greenhouse effect are attributed to steady increases in concentrations of carbon dioxide and other atmospheric gases from anthropogenic sources.

These examples of cumulative environmental change are characterized by broad temporal and spatial dimensions. Changes occur over time scales much longer than forecasts and assessments normally utilized in planning and policy decisions. Spatial changes transcend the fixed boundaries of local sites to include regional and global scales. Changes over time and space accumulate and compound so that, in aggregate, the effect exceeds the simple sum of previous changes. This temporal and spatial accumulation gradually alters the structure and functioning of biophysical systems, and subsequently affects human activities.

In addition to expanded temporal and spatial dimensions, the above examples of cumulative environmental change are also characterized by an activity dimension. Environmental change emanates from ubiquitous human activities, which feature a multiplicity of small, independent decisions by numerous individuals. For example, a single farmer makes annual, seasonal, and daily decisions regarding the management of a land unit. Each decision may result in an increment of environmental change that is individually insignificant but, repeated over time and dispersed over space by a myriad of farmers, may accumulate and contribute to significant environmental change. This process of environmental change attributable to seemingly insignificant decisions has been referred to as "destruction by insignificant incre-

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Table 1. Selected nomenclature relevant to cumulative environmental change

Perspective	Term	Selected reference
Phenomena	Cumulative environmental change	Cocklin and others (1992a,b)
	Cumulative environmental effects	CEARC and NRC (1986), Stull and others (1987)
	Cumulative effects	Preston and Bedford (1988)
Analytical	Cumulative environmental impact assessment	Baskerville (1986)
	Cumulative effects analysis	Salwasser and Samson (1985)
	Assessment of cumulative effects	Stakhiv (1988, 1991)
Evaluative	Cumulative effects assessment	Sonntag and others (1987)
	Cumulative impact assessment	Dickert and Tuttle (1985)
Planning	Cumulative impact analysis	Stakhiv (1988, 1991)
	Cumulative environmental assessment and management	Lane and others (1988), Gosselink and others (1990)
	Cumulative impacts management planning	Williamson (1990)
		Gosselink and others (1990)

ments" (McTaggart-Cowan 1976, Gamble 1979) and the "tyranny of small decisions" (Odum 1982). These dimensions of time, space, and activity define the essence of cumulative environmental change and serve to distinguish its various types.

Although cumulative environmental change and its consequences for ancient and modern civilizations are readily apparent, it has been widely recognized only in the last two decades. Its recognition can be largely attributed to the scientific basis and institutional context of environmental impact assessment (EIA), although views differ as to whether this development is an evolutionary maturation, or a reaction to the shortcomings of more than 20 years of EIA theory and practice. While conceptual frameworks of cumulative environmental change continue to emerge (e.g., Contant and Wiggins 1991, Irwin and Rodes 1992, Stakhiv 1991), theoretical constructs and commonly accepted definitions are still incomplete. Opinions also diverge regarding approaches to the systematic evaluation of cumulative environmental change, or cumulative effects assessment (CEA). One approach views CEA as an extension of the analytical component of EIA (e.g., Bronson and others 1991, Conover and others 1985), while the other regards it as a correlate of regional or comprehensive planning (e.g., Bardecki 1990, Hubbard 1990, Stakhiv 1988, 1991). In addition, the evolving legislative basis and regulatory approach to CEA differs between countries such as Canada and the United States, reflecting not just different political and judicial systems, but also conceptual and institutional dissimilarities analogous to each country's approach to environmental assessment in general.

This review article identifies and describes conceptual frameworks of cumulative environmental change. A general model of causality is a common basis of these frameworks. The article also distinguishes two approaches to cumulative effects assessment and argues for a plurality of approaches. Finally, the article examines legislative and institutional approaches to cumulative effects assessment, particularly in Canada at the federal level, but with some comparisons with other jurisdictions, notably the United States. We begin with a brief survey of nomenclature and a critique of EIA to illustrate its contribution to the scientific and institutional recognition of cumulative environmental change.

Nomenclature

A bewildering array of terms and definitions has emerged to describe cumulative environmental change. These can be broadly grouped into four categories (Table 1), reflecting the varying perspectives from which cumulative environmental change is examined. One category focuses on the phenomena that are subject to cumulative change. A second perspective relates to the process of analyzing environmental change. Scientific definitions highlight analytical attributes such as time and space, or process of accumulation (e.g., CEARC 1988, Horak and others 1983). The third category involves evaluation, determining the relative significance or importance of environmental changes. Legal definitions of cumulative environmental change focus on the significance of a human action relative to other past, present, or future actions (e.g., Cobourn 1989, Schneller-McDonald and Horak 1988). Evaluation is taken a step further in the final category, where the terms refer to a planning interpretation wherein normative evaluation is used to prioritize or select actions or plans. Planning definitions stress an evaluative function to compare and rank alternative plans for their ability to meet predetermined objectives (e.g., Hubbard 1990, Stakhiv 1988, 1991). Throughout the four categories, the term "environment" is interpreted in a variety of ways, sometimes limited to biophysical phenomena, at other times extended to include economic and social components. For some analysts, "effects" is restricted to modifications in biophysical systems, whereas "impacts" refer to ramifications for human systems.

In this article, use of the term "cumulative environmental change" follows that of Cocklin and others (1992a). Cumulative environmental change and cumulative effects are used interchangeably to refer generally to the phenomenon of temporal and spatial accumulation of change in environmental systems in an additive or interactive manner. Cumulative environmental change may originate from either an individual activity that recurs over time and is spatially dispersed or multiple activities (independent or related) with sufficient temporal and spatial linkages for accumulation to result. The process of systematically analyzing or evaluating cumulative environmental change is referred to as cumulative effects assessment (CEA). While the concept of cumulative environmental change and CEA are applicable to socioeconomic systems (e.g., Braid and others 1985), this article focuses mainly on the biophysical elements and processes of environmental systems.

Cumulative Environmental Change and EIA

The concept of cumulative environmental change and the legislative and administrative mechanisms overseeing cumulative effects assessment relate to the scientific basis and institutional context of environmental impact assessment. This section briefly summarizes the main contributions of EIA and then describes key shortcomings that impede the ability of environmental impact assessment to analyze and evaluate cumulative effects.

Three noteworthy developments in EIA have contributed to the recognition of cumulative environmental change and a process for its assessment. First, EIA has augmented the theoretical understanding of environmental change through empirical analysis and modeling of the response of environmental systems to human-induced perturbations. Second, EIA has fostered the development of various analytical methods for projecting and assessing environmental changes associated with proposed human activities. These methods provide principles and design criteria for developing approaches and techniques to analyze and assess cumulative environmental change (see Cocklin and others 1992b, Horak and others 1983, Johnston and others 1988, Lane and others 1988, Stakhiv 1988, 1991, Stull and others 1987, 1988, and Witmer and others 1988). Finally, regulatory and administrative mechanisms for EIA have contributed to the integration of environmental considerations in decision making. This experience should provide a basis for designing institutional approaches to cumulative effects assessment.

Despite these achievements, EIA is constrained by analytical and administrative shortcomings that impede its ability to analyze and assess cumulative environmental change. Analytically, there are temporal and spatial constraints that predetermine the type of impact analysis carried out. Temporal boundaries are commonly characterized by short time frames, usually determined by a project's life cycle with primary emphasis on the implementation phase. Spatial boundaries are typically confined to local scales, usually delineated by project or jurisdictional perimeters. Limited temporal and spatial dimensions generally narrow impact analysis to consideration of single perturbations, simple cause–effect relationships, first-order impacts, immediate effects, a specific environmental attribute, and an individual site. This limited scope overlooks environmental change involving multiple perturbations, complex causation, higher-order impacts, interacting processes, time lags, and extended spatial boundaries (Beanlands and Duinker 1983, Bedford and Preston, 1988).

Limitations on the administrative and regulatory side relate to EIA's reactionary approach and project level focus. An EIA process is usually triggered after a decision has been made to initiate a development activity. The inertia of this initial decision restricts the ability of EIA to influence an activity's original justification and design, and preempts a proactive or anticipatory approach which may be more instrumental in managing certain types of cumulative environmental change (e.g., carbon dioxide and chlorofluorocarbon emissions). Current legislation may require EIA of policies, programs, and projects, but application is more common at the individual project level. This site-specific focus tends to constrain the temporal and spatial scope of impact analysis, disregarding long-term processes and lags, and cross-boundary movements, which are characteristic of many cumulative effects. It also overlooks the additive or interactive effects among environmental changes originating from two or more individual projects. Further, a project focus tends to disregard environmental change induced by higher levels of decision making (programs and policies), which are frequently the driving forces behind individual projects. Finally, the administrative and regulatory process is necessarily selective in that not all types and levels of decision making are assessed for their environmental effects. Farming is an example of an activity generally exempt from EIA requirements, yet cumulative environmental change originating from agricultural activities can be widespread and significant. Historically, EIA has not adequately addressed cumulative effects emanating from spatially and temporally variable processes, the interaction of multiple projects, and program and policy decisions.

In response to the above shortcomings, the scientific basis and institutional context of environmental impact assessment are shifting to incorporate consideration of cumulative environmental change. Analytical shifts include expanded spatial boundaries apparent in regional approaches to environmental assessment (Cooper and Zedler 1980, FEARO 1984, Hunsaker and others 1990), extension of existing EIA methodologies for cumulative effects analysis (Conover and others 1985, Kelly and others 1987), and monitoring of cumulative effects (Carley 1984). Administrative shifts include "tiering" or the flexible application of EIA to projects, programs, or policies (Lee 1982, O'Riordan and Sewell 1981, Sigal and Webb 1989, Wood and Dejeddour 1992), and regulatory actions and organizational reforms that explicitly recognize cumulative effects (Canadian Environmental Assessment Act 1992, Robinson 1991, Schneller-McDonald and Horak 1988, Stakhiv 1991).

Views differ widely as to whether or not these analysis and administrative adaptations in EIA are sufficient to analyze and assess cumulative environmental change. One perception is that these adaptations represent the maturing of EIA into an overarching environmental assessment framework. This framework may require occasional scientific or institutional adjustments, but the conceptual and methodological bases, and administrative setting, are considered to have developed sufficiently to address cumulative effects. According to this perspective, CEA is a neologism for mature EIA. "CEA will not radically alter the EA (environmental assessment) process; CEA is EA, only better—more comprehensive, more effective—and is therefore an exciting step forward in the evolution of environmental assessment" (Bronson and others 1991, p. iv).

Another perspective regards the analytical and administrative adaptations to contemporary EIA as insufficient to overcome the shortcomings that impede the assessment of cumulative environmental change. This perspective differentiates EIA and CEA, considering the latter as essentially a form of planning. Planning principles and normative values are applied to evaluate various trade-offs among alternative economic, social, and environmental objectives and to select an acceptable plan. Analysis of cumulative impacts ". . . is the correlate or obverse side of comprehensive, multiobjective planning" (Stakhiv 1991, p. 116). CEA is seen as the dominant framework or tool to select the optimal path from among possible future growth scenarios. EIA is still considered a part of this framework, but is relegated to its traditional role of generating information, including information on cumulative effects, for specific project decisions.

Emerging Conceptual Frameworks

Two distinct conceptual developments have contributed to the notion of cumulative environmental change. Early scholarly work focused on differentiating key attributes of cumulative environmental change, while more recent research has focused on a model of causality.

Attributes of Cumulative Environmental Change

There is a general consensus among researchers (e.g., Bedford and Preston 1988, CEARC 1988, Clark 1986, Lane and others 1988, Sonntag and others 1987, Vlachos and Hendricks 1976) that cumulative environmental change can be characterized according to three attributes:

1. Temporal accumulation, which occurs when the interval between perturbations is less than the time required for an environmental system to recover from each perturbation. The rate of temporal accumulation may be continuous, periodic, or irregular and occur over short or long time frames;
2. Spatial accumulation, which is analogous to temporal accumulation and results where spatial proximity between perturbations is smaller than the distance required to remove or disperse each perturbation. Spatial accumulation may be characterized by scale (local, regional, global), density (clustered, scattered) and configuration (point, linear, areal);
3. The nature of human-induced activities or perturbations, which also affect the accumulation of environmental change, provided the perturbations are sufficiently linked in time and space as described above. Activities may vary by number, type and magnitude.

These attributes of time, space and activity are not mutually exclusive but rather highly interdependent. Their interaction generates the complexity inherent in cumulative environmental change. These attributes underlie methodological approaches to analyzing and assessing cumulative effects. They also augment the theoretical development of a causal model of cumulative environmental change.

Frameworks of Cumulative Environmental Change

Conceptual frameworks of cumulative environmental change are invariably based on a general model of causality, consisting of three components: cause or source of change, process of change, and result of effect. Early applications of this model are evident in the conceptual framework first proposed by Horak and others (1983), and subsequently refined by Sonntag and others (1987). These frameworks embody three main elements, each corresponding roughly to the model components of cause, process, and effect:

1. Perturbations—naturally occurring events, or human-induced actions, over time and space which contribute to cumulative environmental change;
2. System structure and processes—the receiving ecological, economic, and/or social systems affected by the perturbations, and the temporal and spatial processes influencing system response or recovery; and
3. Effects—the change in a system's structure and functioning over time and space.

These components are evident in two recent works that propose broad conceptual frameworks of cumulative environmental change. Contant and Wiggins (1991) suggest a framework based on the development and environment contexts in which a proposed activity is placed. The development context focuses on the interrelationships among and accumulation of past, present, and future activities in a region. The environment context emphasizes the structure and functioning of the biophysical system affected by a proposed activity. Two categories of cumulative effects result from these contexts: effects resulting from the relationship of an activity to other activities (e.g., incremental development, growth inducement); and effects resulting from changes to the biophysical system (e.g., crowding over time or space, synergism, cross-boundary interactions). In this framework, the development context, environment context, and typology of effects parallel the three components of the causal model.

Cocklin and others (1992a) have refined the model's application further by differentiating: sources of cumulative change, pathways of accumulation, and impact accumulation. Sources of cumulative change are recognized as single or multiple in origin, and similar or diverse in type of development activity. Pathways of accumulation include indirect, nonlinear, and synergistic environmental processes. Impact accumulation involves two broad categories of cumulative environmental change: "accumulation of impacts" refers to unrelated or unconnected effects originating from either single or multiple activities (e.g., thermal cooling from power generation and phosphate loading from farm runoff in a lake); whereas "accumulative impact" alludes to interactive effects emanating from additive, compounding, or synergistic processes (e.g., synergistic chemical reaction among pesticide residues). The following discussion elaborates on each of the three components which together comprise the basic conceptual framework.

1. Sources of cumulative environmental change. Human-induced perturbations are major sources of cumulative environmental change. These sources may be characterized by the number, type, and temporal and spatial extent of human activities. Sonntag and others (1987) classify human-induced perturbations into four categories: (1) a single activity is an individual development or event usually well bounded in time and space (e.g., construction of hydroelectric dam); (2) a multicomponent activity is two or more related developments or events undertaken simultaneously or in sequence (e.g., access roads, hydroelectric dam, transmission corridor); (3) multiple activities are varied types of developments over extended time and space (e.g., energy, transportation, and urban development in a river basin); and (4) a global activity is one or more actions or events widely dispersed over time and space (e.g., fossil fuel use, agriculture, and rainforest depletion all contributing to global warming).

This classification illustrates the diverse causes of cumulative environmental change. These causes escalate in complexity as the number, type, and temporal and spatial magnitude of human activities increase. The first category is somewhat restrictive in that it limits consideration of a single type of activity to fixed temporal and spatial boundaries. Relaxing these boundaries would include consideration of a single activity that is temporally and spatially repetitive. Clear-cutting in forests and drainage in agriculture are examples of single activities that are repeated through time and across space.

2. Pathways of cumulative environmental change. Environmental change may progress through different pathways or processes. As with sources of change, these pathways may vary by number, type, and temporal and spatial characteristics. A perturbation may follow single or multiple pathways and involve additive or interactive processes. Pathways may vary temporally (e.g., instantaneous or with time lags) and spatially (e.g., local, regional or global). Attributes of the perturbation (source of cumulative change) and the environmental system determine the specific pathway(s) of accumulation.

A simple classification scheme focusing on pathways of cumulative environmental change has been proposed by Peterson and others (1987). Four pathways are differentiated by the source of change (single or multiple actions) and type of processes (additive or interactive). Pathway 1 is distinguished by a single action that persistently adds, or removes, without interactive relationships, materials or energy within an environmental system. An example is the slow but steady contamination of an aquifer by deep bedrock nuclear waste disposal. Pathway 2 is also characterized by a single action that persistently adds, or removes, materials or energy but involves interactions through processes such as biomagnification of pesticide residue in the food chain. Pathway 3 involves two or more actions that induce environmental change in an additive but nonsynergistic manner. An example is the release of carbon dioxide and chlorofluorocarbons into the atmosphere where each exhibit separate chemical processes but both are contributors to potential increases in global mean temperatures due to the greenhouse effect. Pathway 4 is comprised of multiple actions with synergistic interaction. Synergism occurs when the total effect of an interaction between two or more processes is greater than the sum of the effects of each individual process. An example is photochemical smog, an atmospheric pollutant derived from the chemical reaction of single air contaminants, nitrogen oxides and hydrocarbons, and ultraviolet radiation.

This classification of pathways distinguishes various processes that contribute to cumulative environmental change. The classification is heuristic since the four pathways are not mutually exclusive in time and space. In a complex environmental system, several pathways may function simultaneously, or thresholds and time lags in one pathway may activate another. An important contribution of this classification is a recognition of the dynamic and complex nature of the pathways contributing to cumulative environmental change. It also questions the common premise that an incremental change in an environmental component or process is similar to the previous unit of change (Cocklin and others 1992a). The classification acknowledges pathways characterized by interactive and nonlinear behavior, natural variability, thresholds, and structural surprises (Beanlands and Duinker 1983).

The operational utility of this classification of pathways is yet to be tested, although Cada and Hunsaker (1990) use it to organize and examine environmental impacts associated with multiple hydroelectric projects in three river basins in the United States. They concluded that early identification of potential pathways through which environmental changes are likely to occur is a critical step in basinwide environmental assessments.

3. Cumulative environmental effects. Cumulative environmental effects have been classified in a number of ways. Baskerville (1986) distinguishes cumulative effects based on an environmental system's response to perturbations (e.g., incremental change in a ecological element or process, systemic or structural change, and environmental change accumulating repetitively over time and space). Cline and others (1983) employ a matrix consisting of a traceable (direct or indirect) impact dimension and an additive (incremental or cumulative) impact dimension. Matrix quadrants identify primary, secondary, aggregate, and synergistic effects. Stakhiv (1988, 1991) subsequently modified this matrix to include a temporal (past, present, future) dimension. The matrix is distinctive in that it differentiates cumulative effects according to the manner in which environmental change accumulates.

Another matrix proposed by Lane and others (1988) characterizes four types of cumulative effects by their primary driving force (cause) and their basic spatial pattern (effect). These types are: (1) proponent-driven, large, single projects that induce environmental change over a large region; (2) proponent-driven, multiple projects (related or unrelated) that interact, resulting in spatially diffuse and complex environmental change; (3) ecosystem-driven (no identifiable proponent), catastrophic, or sudden events (natural or anthropogenic origin) with abrupt environmental change; and (4) incremental and widespread ecosystem-driven (no identifiable proponent) environmental changes attributed to diverse temporal and spatial processes. In this matrix, the emphasis on spatial pattern minimizes the recognition of temporal attributes. Nevertheless, the matrix makes a useful contribution by discriminating cumulative environmental change according to their cause–effect relationships.

Another typology of cumulative effects is that of CEARC and NRC (1986), which differentiates effects primarily on the basis of temporal and spatial attributes. Subsequently expanded by Sonntag and others (1987) and CEARC (1988), the typology identifies eight types of cumulative effects:

1. Time crowding is characterized by frequent and repetitive environmental change that exceeds the temporal capacity of an environmental medium to assimilate or recover from that change. An ex-

ample is harvesting forests at rates that exceed stock regeneration time.

2. Space crowding is portrayed by a high spatial density of environmental change that can alter a region's spatial pattern (e.g., habitat fragmentation) or its spatial processes (e.g., merging of air pollution plumes).
3. Compounding or synergism occurs when two or more environmental changes contribute to another environmental change. For example, various pesticides may interact chemically to produce different toxic compounds.
4. Time lags indicate delays between exposure to a perturbation and response. Carcinogenic effects generally require long-term exposure before symptoms emerge.
5. Space lags or extended boundaries result where environmental change appears some distance from the source. For example, acid rain originating from thermal power plants is frequently deposited in other locations.
6. Triggers and thresholds indicate disruptions to environmental processes that fundamentally alter system behavior. Continued increases in atmospheric carbon dioxide levels are expected to change the global climate system.
7. Indirect effects refer to higher order environmental changes produced at a time or location beyond that of the initial perturbation, or by a complex pathway. An example is the James Bay hydroelectric project, where reservoir flooding contributed to the release of toxic methyl mercury, which, through biomagnification, contaminated commercially valued fish species and closed down fisheries.
8. Nibbling or patchiness effects are incremental or decremental forms of environmental change that usually involve one of the above categories. Examples include gradual fragmentation and loss of natural areas (wetlands, woodlots), and piecemeal shoreline developments (ports, condominiums, marinas).

This classification scheme provides a conceptual typology for differentiating cumulative effects primarily on the basis of temporal and spatial attributes. However, as Cocklin and others (1992a) point out, the scheme mixes typological criteria, for example, some categories refer to processes of environmental change (e.g., time crowding, space crowding), others to form or structure (e.g., nibbling or patchiness), and others to indicators (e.g., thresholds). Furthermore, the operational utility of the typology is yet to be tested in an applied environmental assessment. Despite these shortcomings, the typology exemplifies the types of cumulative effects to be considered in environmental assessments.

The above frameworks of cumulative environmental change are based on the three components of a general causal model. Some frameworks emphasize the causal component (types of human-induced perturbations), others focus on the processes involved (pathways of environmental relationships), and still others relate to the effects (matrices and typologies of environmental change). Collectively, they represent a model of cumulative environmental change that recognizes multiple causation, complex interrelationships, and temporally and spatially variable effects.

Assessing Cumulative Environmental Change: Analysis or Planning?

Cumulative effects assessment (CEA) is the process of systematically analyzing and evaluating cumulative environmental change. Diverging perspectives on the evaluation process have led to two distinct but related approaches to CEA. The prevalent approach regards CEA primarily as an information-generating activity using the principles of research design, and scientific analysis (Baskerville 1986, Bedford and Preston 1988, Bronson and others 1991, CEARC and NRC 1986, Clark 1986, Gosselink and others 1990, Horak and others 1983, Hunsaker 1989). The aim is to analyze and assess cumulative effects associated with past, present, or proposed human activities. A premise of this approach is that scientific analysis and assessment of cumulative effects will be communicated to decision makers, leading to more rational decisions. CEA is considered distinct from planning or decision making but linked to it through information flow. In this approach, cumulative effects assessment is viewed as essentially an extension of the scientific component of environmental impact assessment (EIA).

A second, less common approach to CEA utilizes planning principles and procedures to determine an order of preference among a set of resource allocation choices. Preference is based on explicit social norms that act as decision rules to compare and rank alternative choices and to trade off environmental, economic, and social objectives that define alternative future scenarios. This application of social norms to alternative allocation choices is analogous to multicriteria evaluation and its use in planning (Voogd 1983). The aim is to facilitate the decision-making process by systematically selecting a preferred choice. This approach views cumulative effects assessment as a correlate to regional or comprehensive planning (Bardecki 1990, Davies 1991, Hubbard 1990, Jacobs and Sadler

1990, Stakhiv 1988, 1991, Williamson 1990). It includes a multigoal orientation, the influential role of social norms in determining goal achievement, and a participatory function in decision making.

The distinction between the two approaches is one of emphasis. The scientific emphasis is on the analysis of cumulative effects, whereas the planners come at the problem from a normative policy perspective. Certainly, one approach does not preclude the other, and for effective management they are both essential. For example, a planning approach to CEA can provide the regional context for assessing the cumulative significance of any proposed human activities at the site level. Conversely, a scientific analysis of cumulative environmental change attributable to past, present, or anticipated development actions provides information pertinent to the setting of environmental, economic, and social goals for planning and to the evaluation of alternative courses of action. This pragmatic complementarity suggests that the two approaches are not representative of competing paradigms but rather different interpretations of the scope of CEA. The scientific approach adopts a narrower focus, emphasizing an analytical function, whereas the planning approach adopts a broader definition to also include normative evaluation and management. Each approach can yield a particular contribution to the analysis, assessment, and management of cumulative environmental change.

The distinction between scientific and planning approaches is not unique to cumulative effects assessment. It is also apparent in the evolution of environmental impact assessment generally. The original mandate of the United States National Environmental Policy Act (NEPA) of 1969 is frequently interpreted as an edict for comprehensive environmental planning rather than the information-generating activity it has become with its focus on the environmental impact statement (Andrews 1973, Stakhiv 1991). This interpretation is further reflected in the terms "integrating EIA into planning" to denote complete merging of an EIA process with a planning process, and "EIA of plans" to infer an adjunct EIA process that intersects with planning at a discrete point in the decision process (Armour 1990, Wood 1988). The latter is by far the more prevalent view and practice.

The narrowing of NEPA's original mandate and the failure of EIA to merge fully with the planning process over the last two decades have contributed to a call for the resurgence of regional or comprehensive planning under the guise of cumulative effects assessment (Davies 1991, Lane and others 1988, Hubbard 1990, Stakhiv 1988, 1991). However, its realization is constrained by similar factors that impeded the integration of EIA into planning. First, in addition to the demand for information, decision making is characterized by the interaction of economic, social, and environmental values and trade-offs among these values in the political arena, often resulting in a disjointed, incremental approach to planning (Hollick 1981). Second, the planning process is typically institutionally fragmented with responsibilities for economic planning, environmental planning, and social planning partitioned among multiple agencies. Third, CEA by definition requires the setting of broader spatial boundaries, but planning is typically carried out at local or subregional scales to avoid overlapping jurisdictional problems. These barriers hamper the widespread acceptance and implementation of a regional or comprehensive planning approach to CEA.

A scientific approach to cumulative effects assessment has progressed further in its realization than a planning approach for several reasons. First, scientific criticism of the research design and analysis in environmental impact statements, which included inadequate data on cumulative effects (e.g., Beanlands and Duinker 1983), prompted researchers to improve the theoretical and analytical bases for investigating environmental change. Second, the legislative and administrative components of EIA, with only minor adaptations, provided an institutional context for CEA. Third, and perhaps most importantly, planning and decision-making processes responded to the increasing complexity of environmental problems by demanding more scientific information, rather than altering the priority of social norms or restructuring planning institutions.

Institutional Perspectives

Future prospects for a scientific or planning approach to cumulative effects assessment are greatly influenced by the institutional response to CEA. The legislative and administrative setting for cumulative effects assessment are illustrated for the cases of the United States and Canada. Only highlights are presented, particularly of the American experience, since detailed reviews are available elsewhere (Cobourn 1989, Herson and Bogdan 1991, Hirsch 1988, Parry 1990, Schneller-McDonald and Horak 1988).

United States

The National Environmental Policy Act (1969) (NEPA) of the United States is generally acknowledged as the original legislative impetus for cumulative effects assessment (Schneller-McDonald and Horak 1988), even though the act does not explicitly mention cumulative effects. Subsequent regulatory amendments and judicial interpretations have provided the legal framework requiring assessment of cumulative effects. Most prominent are the 1978 regulations promulgated by the Council on Environmental Quality (CEQ) which defines cumulative impacts as:

> the impact on the environment which results from incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time [CEQ 1978 40 CFR section 1508.7 as quoted in Schnellar-McDonald and Horak 1988, p. 6].

These regulations broadened the scope of an environmental impact statement to include consideration of cumulative effects, particularly interactions among multiple developments. This implies that the effects of a single action may be deemed insignificant but, when assessed relative to other (past, present, reasonably foreseeable) actions, judged cumulatively significant.

In addition to the CEQ regulations, other federal laws also contain explicit requirements for cumulative effects. For example, the Surface Mining Control and Reclamation Act requires that mining permit applications assess the cumulative effect of all anticipated mining in an area on the region's hydrologic balance. Similarly, the Clean Water Act (1977) requires an assessment of cumulative effects associated with nonpoint sources of pollution from agriculture and silviculture, including return flows from irrigation.

Individual states have also passed regulations requiring the assessment of cumulative effects (e.g., California, Florida, New York), often patterning these regulations after the federal CEQ guidelines. State regulations overseeing the assessment of cumulative effects have been studied by several researchers (e.g., Cobourn 1989, Cowart 1986, Parry 1990).

Federal and state agencies with resource management and environmental protection responsibilities are increasingly implementing policies and procedures to incorporate cumulative effects assessment into decisions. For example, permit decisions by the US Army Corps of Engineers routinely include an evaluation of the cumulative effects of a proposed development action affecting wetlands (Stakhiv 1988, 1991), and the California Department of Forestry and Fire Protection (1991) is preparing guidelines to assist professional foresters to assess watershed level cumulative impacts that may result from proposed timber operations.

Canada

Canada's institutional and legislative response to cumulative environmental change emerged more slowly and less formally than in the United States (Table 2). Consideration of cumulative effects is apparent in some resource decisions of the 1970s, particularly energy-related developments in Canada's north. McTaggart-Cowan (1976) coined the phrase "destruction by insignificant increments" to refer to the accumulation of minor impacts from individual projects into a total or cumulative effect from all projects on the Mackenzie Delta (see also Gamble 1979). The Berger Inquiry appraised the interactive and stimulative nature of multiple northern energy projects, and concluded that "the cumulative impact of all these developments will bring immense and irreversible changes to the Mackenzie Valley and the Western Arctic" (Berger 1977, p. ix).

Provisions requiring assessment of cumulative effects are not contained in the original (1973) cabinet directive establishing the federal Environmental Assessment and Review Process (EARP), nor in the subsequent revisions (1978 and 1984), but they are gradually acknowledged by the Environmental Assessment Panels established by EARP (Table 2). Terms of reference (TOR) for and reports by early EARP panels do not address cumulative effects per se, although expanded spatial boundaries are occasionally evident in regional development scenarios. By the mid-1980s, cumulative effects were not yet specifically mentioned in TOR but panel reports generally acknowledge them. For example, the Beaufort Sea Environmental Assessment Panel [Federal Environmental Assessment Review Office (FEARO) 1984] requested the proponent to examine the cumulative effects of hydrocarbon production and transportation on selected mammal species, even though there were few precedents for this type of analysis in Canada (Sadler 1990). More recent panel TOR (e.g., FEARO 1990a) and panel guidelines for the preparation of environmental impact statements (e.g., FEARO 1990b) have included explicit references to cumulative effects.

Seventeen years after creating EARP, the only piece of legislation referring explicitly to cumulative effects is the Canadian Environmental Assessment Act (1992). The act stipulates that every screening or mandatory study of a project, and every mediation or assessment by a review panel, is to include consider-

Table 2. Emergence of cumulative effects assessment in Canada, selected highlights 1973–1992

Year(s)	Institutional or legislative response	Comment
1973	EARP[a] approved by cabinet	Cumulative effects are not mentioned
1975	CARC[b] conference on Mackenzie Delta	Scientific recognition of cumulative impacts of multiple resource developments
1977	Berger Inquiry	Addresses cumulative impact of piecemeal northern development
1978–1983	EARP environmental assessment panels (e.g., Eastern Arctic, Lancaster Sound)	TOR[c] do not include cumulative effects, regional focus utilized
1984–1985	EARP environmental assessment panels (e.g., Beaufort Sea, CN Rail Twin Tracking)	TOR do not include cumulative effects but raised in Panel reports
1986–1988	CEARC[d] workshop and research reports	Scientific and management aspects of cumulative effects
1990	EARP environmental assessment panels (e.g., Northumberland Strait Crossing, Toronto Airport Expansion)	TOR explicitly include cumulative effects
1991	Resource development agencies consider cumulative effects assessment (CEA)	e.g., Ontario Hydro's CEA of the Moose River Basin Hydroelectric Development Plan
1992	Canadian Environmental Assessment Act	Requires consideration of cumulative effects

[a]Environmental Assessment and Review Process.

[b]Canadian Arctic Resources Committee.

[c]Terms of reference.

[d]Canadian Environmental Assessment Research Council.

ation of: "the environmental effects of the project, including the environmental effects of malfunctions or accidents that may occur in connection with the project and any *cumulative environmental effects* that are likely to result from the project in combination with other projects that have been or will be carried out" [Canadian Environmental Act (1992) section 11.(1)(a); emphasis added]. Cumulative environmental effects are not defined in the act and procedures for their assessment are not given.

Acknowledgement of cumulative effects by recent EARP panels and their explicit inclusion in the Canadian Environmental Assessment Act are likely to influence other levels of government and resource development agencies (Table 2). For example, Ontario Hydro, the province's main energy utility, is proposing a "pilot" cumulative effects assessment entailing multiple hydroelectric developments and redevelopments for up to 12 sites within the Moose River Basin in northern Ontario (Bronson and others 1991).

While the regulatory context of CEA is very recent, cumulative effects have been examined in an important series of research reports focusing on scientific and management aspects (Table 2). Carley (1984) developed a cumulative socioeconomic monitoring program for the Beaufort Sea region to evaluate the impacts of multiple energy-related developments on northern local communities and economies. A binational (American–Canadian) workshop examined generic scientific and management aspects of cumulative environmental effects [Canadian Environmental Assessment Research Council (CEARC) and US National Research Council (NRC) 1986]. Follow-up studies to the workshop investigated theoretical, analytical, and organizational facets (Peterson and others 1987, Sonntag and others 1987), which resulted in a research prospectus (CEARC 1988). Efforts to implement recommendations from the prospectus are ongoing (Munn 1990). Collectively, these research efforts are thrusting the issue of cumulative effects into the forefront of environmental assessment in Canada. The institutional and legislative response can be attributed, in large part, to this combined research effort.

Comparison of Institutional Perspectives

Three observations are made regarding American and Canadian legislative and institutional responses to cumulative effects assessment. First, Canada's emphasis on institutional procedures, with delayed legislative initiatives, contrast with the relatively early regulatory and judicial approach of the United States. The American approach provided a legal mechanism to incorporate cumulative effects into decisions and an elevated role for the courts to interpret and enforce this mechanism. Numerous court cases have ruled specifically on the matter of cumulative effects (Schnellar-McDonald and Horak 1988, Herson and Bogdan 1991). In Canada, a decision to assess cumulative effects is discretionary and influenced by expert judgment, stakeholder participation, and political expediency. In place of the courts, Canada has historically relied on quasijudicial environmental assessment panels, although 1989 and 1990 federal court rulings concerning the Rafferty-Alameda and Oldman River dam projects (Robinson 1991) may set a legal precedent for enforcing consideration of cumulative effects.

Second, in both Canada and the United States, the emergence of cumulative effects assessment parallels a broadening of the scope and role of environmental impact assessment. Administrative reforms and regulatory amendments governing a broadened EIA process have included explicit provisions for the assessment of cumulative effects. The inclusion of these provisions into a revised EIA process is indicative of a perspective that views environmental assessment as an overarching framework in which cumulative effects assessment is considered a subset of EIA. In this framework, the analysis and appraisal of cumulative effects is deemed a scientific activity designed to generate information for decision making. Legislative actions and institutional adjustments to incorporate consideration of cumulative effects into EIA effectively preempt the emergence of a regional or comprehensive planning approach to CEA.

Finally, the early and brisk regulatory actions of the United States created a demand for information on cumulative environmental change. This demand produced a pragmatic need to develop analytical methods and techniques for the scientific assessment of cumulative effects. Canada's more gradual and piecemeal approach shifted attention from methodological development to conceptual and institutional aspects. While recognizing the need for increased scientific research on cumulative effects, Canadian researchers placed greater emphasis on environmental planning and management and on institutional restructuring than their American counterparts (CEARC 1988, Hubbard 1990, Lane and others 1988, Peterson and others 1987, Sonntag and others 1987, Munn 1990). Notwithstanding these differences in emphasis, recent Canadian legislative and administrative adjustments to EIA indicate that Canada's institutional approach to environmental impact assessment also provides the framework for its approach to cumulative effects assessment, just as NEPA and related CEQ regulations furnish the context for CEA in the United States.

Summary and Conclusions

This article has shown that the emerging concept of cumulative environmental change, and a systematic process for its evaluation, can be largely attributed to the analytical and institutional shortcomings of environmental impact assessment. A review of conceptual frameworks has revealed that a general model of causality underlies the theoretical construct of cumulative environmental change. The article also identifies two distinct but complementary approaches to cumulative effects assessment. A scientific approach regards CEA primarily as an information-generating activity to identify and assess changes in environmental systems brought about by cumulative processes. A planning approach focuses on the use of such information, utilizing social norms as decision rules, to compare and rank alternative choices, to trade-off environmental, economic, and social objectives, and to initiate management actions. Finally, the future prospects of each approach have been examined by comparing the institutional responses to CEA in Canada and the United States.

Conceptual frameworks of cumulative effects vary in their emphasis on the different components of the causal model. Some accentuate the source of cumulative environmental change, others focus on pathways of cumulative environmental change, and still others classify types of effects. Together, these frameworks contribute to a model of cumulative environmental change that integrates multiple causation, interactive processes, and temporally and spatially variable effects.

A plurality of approaches to cumulative effects assessment is needed. A scientific approach to CEA is required to supply information demanded by decision makers about the cumulative nature of human-induced environmental change. This approach can contribute to theoretical development, methodological techniques, and empirical findings to advance the understanding of cumulative environmental change. This is the role of the analyst. A planning approach to CEA is needed to incorporate knowledge of cumulative effects into the decision process. The role of the planner is to take advantage of scientific insights so that decisions are based on the best available understanding of interactions between human and environmental systems. Acceptance of both approaches recognizes that each provides a particular contribution to the analysis, evaluation, and management of cumulative environmental change.

The ongoing challenge is to continue to apply and empirically test the conceptual frameworks and approaches to CEA in cases of human-induced environmental change. This demands assessment and refinement of existing methods of cumulative effects analysis and, where warranted, design and testing of new analytical tools capable of investigating cumulative effects. Methodological development will be precipitated by an increasing demand for scientific information to manage complex environmental problems.

Finally, the institutional and legislative context for cumulative effects assessment is likely to be that within which EIA has evolved. This is readily apparent in the regulatory and administrative revisions to EIA in Canada and the United States, which explicitly incorporate consideration of cumulative effects into a broadened EIA process. Continued institutional and legislative adjustments to this process are likely as the practice of cumulative effects assessment matures.

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