What Does Cumulative Effects Analysis Have to do With Sustainable Development?

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The equation of animal and vegetable life is too complicated a problem for human intelligence to solve, and we can never know how wide a circle of disturbance we produce in the harmonies of nature when we throw the smallest pebble into the ocean of organic life.

George Perkins Marsh, 1864.

More than a century ago Marsh, in the statement above, made two important observations about human-environment interaction. One was his recognition of the far reaching disturbances that human activities, irrespective of their scale, can bring to natural systems -- the wide circles of disturbance. The other observation related to our limited understanding of how natural systems function and respond to human actions.

If we accept the U.S. National Environmental Policy Act (NEPA) as the first direct attempt to modify planning procedures such that the impacts of human activities upon the environment are given due consideration, then it was about 100 years before western societies began to accept a responsibility for the problems that Marsh had been referring to. Unfortunately, the environmental impact procedures that were developed subsequent to NEPA have taken...
a rather narrow view of the "circles of disturbance". Perhaps in some part this is attributable to the inherent complexity of the "equation of animal and vegetable life".

In the mid-1980s, almost 15 years after NEPA, attention turned on a widespread basis to considering human impacts upon the natural environment within a broadened assessment framework. This is based on the notion of cumulative environmental change (CEC) which, in its most general terms, refers to the effects of multiple inputs to, or withdrawals from, natural systems. Explicit in the study of cumulative change is a recognition that the existing state of the environment is not simply the product of individual impacts occurring independently of each other. Environmental change is, in fact, the consequence of many interacting factors, the combined effects of which are not always well understood. It follows that cumulative effects assessment (CEA) is concerned with identifying and evaluating the impacts of multiple inputs (or withdrawals) upon the environment.

The objective of this paper is to argue that notions of cumulative environmental change and its assessment are consistent with sustainable regional development. The argument is developed in three parts. The first looks to conceptual and theoretical perspectives on sustainable development with an aim to identifying potential consistencies with definitions of, and approaches to, cumulative effects analysis. The next part of the argument is a critique of traditional (managerial) approaches to environmental assessment and management. A definition of cumulative environmental change and its assessment is then presented. This prescription offers improvements over approaches to environmental assessment that have prevailed historically, and is more consistent with sustainable regional development. Subsequent to this argument, attention is drawn to some issues relating to the methodology of CEA and a short review of alternative methods is presented.

Defining Sustainable Development

If we examine conceptual and theoretical perspectives on sustainable development, questions emerge about the relevance of environmental impact assessment as it has been practised traditionally. At the same time, an argument can be developed in support of the relevance of cumulative effects analysis to planning for sustainable regional development, if we make certain assumptions about the appropriate nature of CEA itself. The discussion that follows is intended to establish support for CEA in the context of sustainable regional development, in this case with specific reference to conceptual and theoretical consistencies.

Useful definitions of sustainable development are proving elusive. There is certainly widespread endorsement of the now widely touted but nebulous statements, to the effect that sustainable development is about meeting current needs without compromising opportunities for future generations. While a laudable principle indeed, such statements lack specificity, give little direction in terms of appropriate theory, and offer no real potential for assessing in practical terms what is in fact sustainable.

In no small part, the difficulty in achieving clear conceptual articulation has arisen because so many vested interests have adopted the term under the belief, or in the hope, that it legitimises their own values and causes. Norgaard (1988: 607) noted: "Environmentalists want environmental systems sustained. Consumers want consumption sustained. Workers want jobs sustained...With the term meaning something different to everyone, the quest for sustainable development is off to a cacophonous start".

One point of common departure amongst many contemporary commentators is that the term sustainable development refers to a holistic view of how society, economy and environment should evolve. Rees' (1988: 279) attempt to clarify the meaning led to the following observation, for example: "This interpretation suggests that hardly any area of sociopolitical relevance would be unaffected were we to seriously implement sustainable development". The breadth of what is implied by the term is captured as well in Pearce's (1988) list of goals, which he describes as being consistent with sustainable development:

- justice in respect of the socially disadvantaged;
- justice to future generations;
- justice to nature; and
- aversion to risk arising from:

1. our ignorance about the nature of interactions between environment, economy and society; and
2. the social and economic damage arising from low margins of resilience to external 'shock'.

At the more applied level, government agencies and politicians have grasped the idea that sustainable development implies something wide-reaching, but have typically then resorted to reductionist approaches to planning for sustainable development. Amongst the euphoric responses of politicians to sustainable development in the 1980s and 1990s, sector-based agencies of government have been set forth to identify sustainable agriculture, sustainable industry, sustainable forestry and so forth. But even if we accept that reductionist approaches to sustainable development have relevance, sectoral policy must be developed with recourse to a more general principle of sustainable development and, consequently, with reference to other aspects of society and economy. In advocating a human ecology approach, Glaeser (1988) captures this in three points:
1. it would have to be possible to generate it (sustainable development policy) within the context of specific independence and autonomy, as it were out of an inherent principle;

2. its parts, or its application in sectoral policy (in industry, agriculture, health care), would have to be derived from, or at least understandable in terms of, this principle - and not the reverse; and

3. its norms would have to be compatible with the natural and socio-cultural environments in which it is embedded.

What Glaeser suggests in these three points is that sustainable development, even when looked at from a sectoral viewpoint, must be based in a more holistic view of society, economy and environment.

Amidst the burgeoning literature, there are a few notable contributions that have served not only to embellish the broad conceptions of sustainable development, but which have added theoretical elegance to the debate as well. Norgaard’s discourses on co-evolutionary development (Norgaard 1984a, 1984b, 1985, 1988), for example, have rightly become one of the central theoretical contributions. In Norgaard (1988), he captures the holism that is innate to the notion of sustainable development by referring to five “increasingly complex definitions” of sustainable development in a regional context. Beginning with a definition that includes only the material sustainability of a region in isolation, his definition is expanded by increments to include first material and then cultural interactions with other regions, to include the degree of reliance on strategic, non-renewable resources (for example, fossil fuels) and contributions to global environmental change, and at the final stage to define a region that is compatible, materially and culturally, in its development path with a global community.

According to Norgaard, the unsustainability of past development can be explained from an epistemological perspective, with reference to what he has referred to as the “atomistic-mechanistic” view of knowledge and development. A key attribute is the often assumed, but actually non-existent, barrier between changes and relations of the parts (that is, of environmental and social systems) vis-à-vis the essential nature of the whole. Thus: "Action changes the nature of parts and relations, typically in an irreversible manner. We keep introducing totally new parts -- agrichemicals into ecosystems and televisions into social systems -- which create brand new relations. Basing action on science girded by false beliefs in universals and objectivity results in 'unforeseen' changes in social and environmental systems. Thus the unsustainability of past developments has an epistemological explanation" (Norgaard 1988: 613). His co-evolutionary view of development rejects firmly this characteristic reductionism: "Broadly conceived, the call for sustainable development resonates with the rise of new understandings of environmental systems, technology, social organisation, knowledge, values and their interplay. These new understandings reject the modern belief that these realms can be understood separately, that they do not interplay" (Norgaard 1988: 614).

The systems view implied by this statement assumes a symmetrical and balanced set of relationships, with no one system dominating another. Moreover: "Not only is each subsystem related to all the others, but each is changing and affecting the evolution of the others" (Norgaard 1988: 617). Hence: "With each subsystem putting selective pressure on each of the other subsystems, they co-evolve in a manner whereby each reflects the others" (Norgaard 1988: 617).

Although development proceeded historically along a co-evolutionary path, it has been the use of hydrocarbons that has driven "a wedge between co-evolution of social and ecological systems" (Norgaard 1988: 617). Inevitably, a return to a co-evolutionary path of development will bring about a new socio-political order: "With sustainability as a metabelief instead of simply another objective on the agenda, we enter a wholly new political realm. Old objectives will fade away as new unforeseeable ones arise, confounding the political process by making old compromises meaningless while opening up both unexpected opportunities and problems" (Norgaard 1988: 614).

Glaeser’s (1988) concept of sustainable development also emphasises a holistic interpretation, founded in the field of human ecology. Glaeser argues (somewhat like Norgaard) that the relationship between the parts of a system can only be understood with reference to the whole, and not with reference to laws that relate only to the parts. "Thus the repeated dictum of Aristotelian metaphysics that the whole is more than the sum of its parts must be understood qualitatively, not quantitatively (Glaeser 1988: 672). And thus: "...only when a system’s coherence is fully understood can partial areas be understood, hence known" (Glaeser 1988: 672).

Presuming the field of human ecology to be holistic in its epistemological base, Glaeser proceeds to illustrate how a balanced and interactive system is sustainable, first with reference to agriculture and then to development policy more generally. A sustainable agricultural system, he argues, is founded in the production of foodstuffs and the reproduction of the agro-ecosystem by human labour. Thus: "The following general formula applies here: the more reproductive labour is applied, the better the agro-ecosystem functions. The reverse is also true: the less such labour is put in, the greater the danger of environmental destruction" (Glaeser 1988: 675). While nature in some part determines the characteristics of the system, Glaeser strongly asserts that agricultural production is culturally determined also.

Traditional (and sustainable) agrarian culture is then contrasted with modern agriculture, wherein the balance and integration between human activity and environment has been displaced in the latter. "This means that the abstract Homo oeconomicus, a product of money economy and yield maximization,
forces out the concrete tillers of the soil, who were adapted to a cultural and social, ecological and economic structure - who in short existed in a holistic human ecological environment. Economic specialization has been accompanied by loss of culture and history, but also by loss of nature - through the elimination of ecological diversity, for instance - accompanied often by environmental destruction" (Glaeser 1988: 675).

To revert to a development path that is sustainable requires the reintegration of humans and nature: "...it will be necessary to develop strategies for an agriculturally and environmentally sustainable policy which reintegrates into the system of production that type of labour which preserves nature and the traditional landscape or, in the words of environmental economics, to internalize their social costs in the system of agricultural production" (Glaeser 1988: 676).

At a fundamental level, Glaeser's human ecology thesis differs little from Norgaard's co-evolutionary view, in that both emphasise a closely integrated and balanced systems view. What Glaeser's account lacks is the mechanism of change that is quite explicit in Norgaard's writings (that is, co-evolution, through interactive relationships of the parts).

In an interesting discourse on sustainable development, Redclift (1987, 1988) also embraces a holistic interpretation. Redclift correctly observes that social scientists have either ignored, or have had difficulty in dealing with the environment, especially at a theoretical level. Not surprisingly then, treatments of the human-environment interaction are theoretically bereft. In an effort to move the debate forward in this respect, Redclift devotes much of his discussion in Sustainable Development to explaining the relationship between the development of capitalism and the environment. Redclift attempts to explain environmental change as being part of a socio-cultural process as well: "The environment is transformed by economic growth in a material sense but it is also transformed existentially, although we - the environment users - often remain unconscious of the fact" (Redclift 1987: 3). In linking the evolution of systems of production, socio-cultural structures, epistemology and environmental change, Redclift has made an important contribution. Imbedded within this integrated view of society, economy and environment, there are several more specific claims of central importance.

One is that Redclift asserts, like Norgaard and Glaeser, that the epistemological foundations of western mechanistic science lead to a reductionist approach to the understanding of the environment, how it changes and how it is managed. More than this though, the view of knowledge is upheld by existing socio-political structures. Hence: "...it is also important to acknowledge that environmental rationalities are not only socially constructed, they are also supported by social groups with different degrees of power and with conflicting economic interests" (Redclift 1987: 202). Acknowledging this social construction of knowledge, especially in respect of the environment, and putting this in the context of the historical development of capitalist production gives rise to a sobering observation: "...through the use of methodologies developed in the natural sciences, nature has been divested of social control. We are losing control both of the destruction of nature and its recreation" (Redclift 1987: 204).

Also prominent within Redclift’s analysis are the implications of an economic order that is increasingly internationalised. Within this, implications for the poor are of central interest. The international economic order places pressures and demands upon traditional societies, with the consequent effect that patterns of resource use and human-environment interactions are altered fundamentally. Simultaneously, value shifts vis-à-vis the environment within western societies, wherein environmental consciousness is expanding, are being imposed upon these societies, giving rise to some fundamental contradictions. The penetration of capitalism leads to social, economic and environmental transformation, typified by resource exploitation, but Redclift suggests that hitherto autochthonous societies will not emerge into post-industrial societies. Nonetheless, human-environment interactions are altered in fundamental ways, such that the environment is degraded. These comments have important implications in respect of alleviating the situation of the poor, since any analysis must have adequate reference to international geo-political and economic structures.

Explicit within Redclift's writings is a strong belief that traditional cultures will provide vital clues with respect to sustainable development. In short, sustainable development of the environment has no independent ontological status within autochthonous societies, since it is innate to traditional systems of production and reproduction. "The corollary is that, if we want to know how ecological practices can be designed which are more compatible with social systems, we need to embrace the epistemologies of indigenous people, including their ways of organising their knowledge of their environment" (Redclift 1987: 151).

Others have contributed usefully to the theoretical debate and articulation of the concept of sustainable development - Daly's longstanding notion of the steady state economy (for example, Daly 1968, 1977); Page's (1977a, 1977b) discourses on permanent livability; and Chambers (1986) on sustainable livelihood thinking, for example. The selective outline of three perspectives in the discussion above serves sufficiently well in illuminating contemporary holistic interpretations of sustainable development including the theoretical complexity that necessarily follows.

Environmental Managerialism

With respect to environmental quality in particular, a broadened frame of reference is an almost inevitable consequence of our increasing ecological knowledge, combined with better understanding of the relationships between
society, economy and environment. A reductionist approach to environmental problems has traditionally prevailed -- specific issues have given rise to specific policies and programmes, embedded within national policy statements. Hence: "Pollution control, population planning and energy conservation have been incorporated into national policies during the latter 20th century. Pesticide use is regulated, industrial pollution is inveighed against, and family planning is encouraged throughout the world... Agencies for land use planning, pollution control and technology regulation have added fresh layers to the bureaucratic onions of both the developed and developing nations" (Norgaard 1988: 606).

In a rather similar vein, Nijkamp and Soeteman (1988: 621) said: "In many countries environmental pollution has been tackled fairly successfully. Abatement policies, however, have mostly been oriented towards pollution problems of a concrete - often local or regional - nature; witness the large number of regulations that have been introduced in the field of industrial pollution, sewage and the like". Even so: "Where environmental considerations clash with strategic, political or national interests, they are unceremoniously forgotten" (Redclift 1987: 200).

As Nijkamp and Soeteman (1988: 622) observe, however, the awareness of, and interest in, environmental change has undergone something of a transformation in recent times: "In the past decade our world has been confronted with some striking new phenomena in the interlinkage between the environment and socioeconomic activities. One of these is the globalization of environmental impacts. Another is the regionalization of often hardly visible but quite substantial discrepancies in the utilization of environmental resources". The significance of each of these is then clarified. On global environmental change they remark further: "The global impacts of environmental pollution, reflected inter alia in ozonization, desertification, deforestation and acid rain, have come as scientific surprises and have to date scarcely been addressed in actual policy making". And on changes at the regional scale: "The large number of small-scale and marginal changes that have clear regional dimensions should also be mentioned. All these incremental phenomena, which hardly seem important by themselves but have severe environmental impacts, necessitate more coherent planning". The changing perception and understanding of environmental change, which recognise the wider links both in terms of ecosystem functioning and change, as well as the links to socio-political activity, fits firmly within the holistic interpretations of sustainable development.

Conventional approaches to environmental management offer little promise in terms of ameliorating environmental change. This is so for two reasons. One is the epistemological foundations of our science, which is reductionist by nature. The second is that since knowledge is a socio-political construct, traditional environmental management approaches have been designed to conform with, not challenge the existing order. Rees (1988: 280) noted: "The materialist paradigm contains neither the vocabulary nor the concepts necessary for sustainable development. Trapped within the prevailing worldview, society can only conceive ways to force nature to continue meeting our growing demands; it is literally beyond imagining that we should adapt our needs to the constraints of the natural environment".

The significance of these problems was recognised some time ago. Holling (1978), for example, identified the structural impediments to effective environmental assessment. Notably, development objectives are typically established in advance of, and without reference to, environmental and social considerations. Following from this:

"The second major difficulty with the present protective and reactive response is that it makes the practice of environmental assessment arbitrary, inflexible, and unfocused. Each issue is often dealt with as if it were unique, as if the environmental consequences could be separated from the social and economic ones... Such environmental effects induced through social forces are rarely considered. And the reverse is true. Deleterious social and economic impacts can be induced through ecological forces that, if recognized early, could at times be turned to man's benefit rather than simply suppressed and ignored" (Holling 1978: 6).

More recently, the same sorts of concerns have been expressed by Redclift (1987). He notes, for example: "These methods of intervention (e.g., land use planning, pollution control) were designed to facilitate, rather than seriously curtail, the production activities which are central to industrial economies". Thus, it follows that: "Environmental management, imbued with the contradictions that afflict all management sciences, represents an attempt to mediate the contradictions of industrialized society by minimizing the social costs of conflict".

In a later contribution, Redclift (1988) identifies four specific objections to the managerialist tradition that follow from such observations:

1. Environmental managerialism considers the environment after the 'development' objectives have been set;
2. Environmental consequences of development are separated from the social and economic ones within the managerialist approach;
3. The managerialist approach takes as given the distributive consequences which the market produces;
4. The techniques which are a part of environmental managerialism deflect attention from the context of environmental degradation.

In Sustainable Development, Redclift expresses a preference for what is referred to as "Developmental/environmental planning" versus the more tradi-
The Concept of Cumulative Environmental Change

That environmental change is often cumulative in its characteristics has long been acknowledged. Even early prescriptions for environmental impact assessment (EIA) under NEPA made reference to the requirement to consider cumulative impacts (Cobourn 1989). Despite the long-standing recognition of importance, the assessment of cumulative effects has not been a notable feature of EIA in practice.

Since about the mid-1980s, attention to cumulative environmental change and its assessment has become more focused. The 1985 Canada-U.S. binational workshop on cumulative environmental change (CEARC and U.S. NRC 1986) was reflective of the increasing interest, and has proved to be an important catalyst for further research. The literature on cumulative effects has expanded considerably in the subsequent years, addressing definitions, institutional arrangements, methodology and practice (for example, Cobourn 1989; Cocklin et al. 1992a, 1992b; Contant and Wiggins 1991; Rees 1988; Sonntag et al. 1987). Quite recently as well, new legislative provisions for environmental impact assessment and management make direct reference to cumulative effects: Canada’s Bill C13 and the New Zealand Resource Management Act 1991 are notable examples.

Interpretations of cumulative environmental effects assessment remain variable, however, and this is indicative of the quite different approaches taken to definition. Descriptions of CEA sometimes maintain a project focus (as with traditional EIA), but set specific developments in the context of other proximate impacts and, in some cases, address the combined effects of two or more impacts (for example, Contant and Wiggins 1991; Dames and Moore 1981). Underlying such approaches is the view that cumulative environmental effects can be described in terms of activities, wherein it is the combined effects of these that are of significance. In retaining a project focus, such assessments remain reactive in a management sense. The primary emphasis given to activities has the attendant risk also of providing a limited view of environmental change itself.

Elsewhere, greater emphasis has been given to the adjustment processes of ecosystems themselves. From these descriptions of cumulative change emerge references to synergistic effects, bioaccumulation, compounding, and ecosystem fragmentation (for example, CEARC 1988; Sonntag et al. 1987).

In themselves, neither of these approaches is sufficient. Descriptions of cumulative environmental change should encompass the sources of impact, the nature of environmental change (that is, ecosystem response) and the manner in which impacts combine or accumulate. Figure 1 represents an attempt to broaden the definition and concept of cumulative change. The figure identifies explicitly the three main dimensions of environmental change.

1. Sources of change. In the simplest classification, sources of change can be defined as either single or multiple. A single activity, such as an industrial facility, will inevitably have several effects upon the environment, some of which may be interrelated. We can refer to the cumulative changes brought about by this
single activity. From a somewhat different perspective, several operating units of a single type of activity, such as pastoral farming, can have individually minor, but collectively significant environmental effects. This has been referred to elsewhere as "space crowding" (CEARC 1988). More typically, cumulative change is associated with multiple sources of activity. Therein, the concern is focused on the combined impacts of two or more sources of disturbance (for example, of a power station and an industrial facility).

2. Pathways of accumulation. Cumulative environmental change can also be distinguished with reference to the ways in which inputs to the environment combine to bring about disturbance. Two main pathways are recognised: additive/crowding and interactive/compounding (for example, synergistic). An additive/crowding pathway is characterised by the fact that inputs or withdrawals combine in a linear fashion, with each unit of activity creating much the same level of disturbance. A cumulative effect results from the accumulation in spatial and temporal terms (crowding). Interactive/compounding refers to more complex pathways of change, such as synergistic effects or when pollutants accumulate through the food chain (bioaccumulation).

3. Impact accumulation. A distinction can be drawn between an "accumulation of impacts" and an "accumulative impact". The former describes a situation in which there is a diverse range of impacts, perhaps unrelated, which contribute to an overall degradation of the environment (for example, within a region, industry giving rise to air pollution, intensive farming leading to pollution of waterways, and the accumulation of waste products from various human activities). An accumulative impact results when two or more, perhaps unrelated, activities contribute to a single form of environmental disturbance. The burning of fossil fuels releases carbon dioxide and agricultural activities give rise to outputs of methane, both contributing to climate change.

The discussion above is intended to clarify that cumulative change is recognizable in three main dimensions. A cumulative element exists in the sources of disturbance - multiple units of a common type or disparate multiple sources. We can also distinguish different pathways of accumulation - impacts on various environmental components that remain disjunct effectively, or processes that combine impacts additively, synergistically or through compounding (for example, bioaccumulation). We can also distinguish two broad categories of cumulative impact - many disparate impacts upon environmental or social sys-

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**Figure 1:** The Concept of Cumulative Environmental Change

Source: Cocklin (1999).
move away from what Norgaard called the atomistic-mechanistic approaches to environmental management. The managerialist tradition that has typified EIA has been entirely reactive, as discussed above. Environmental management in that context is a response at the margin to anticipated environmental impacts, and a response that does not compromise unduly the central economic development objectives. An alternative approach prescribes a more proactive stance. Environmental management proceeds according to a set of clearly defined objectives, developed with explicit reference to other societal priorities (for example, social, economic, political). Human activity, being one source of change, is examined in the context of the human-environment interaction that gives rise to such activities. Hence, environmental management is not a practice of incremental tinkering, but is based on a set of established objectives and procedures that are given a central place in decision making.

Within only a few years of NEPA, the appropriateness of a proactive approach to environmental assessment had been recognised (Anderson 1973; O’Riordan 1976), but it has not yet found application on a widespread basis. The folly is obvious: “Critics of traditional EA have long observed that in the absence of a broader policy and planning context, without knowing potentially competing resource uses and values, it is impossible to assess the ‘significance’ of impacts associated with isolated projects” (Rees 1988: 286).

A proactive approach of the kind suggested above is a positive response to Redclift’s first two objections to the managerialist tradition. Moreover, in that the proactive approach to environmental assessment and management advocated here integrates human and natural environmental systems in fundamental ways, it is consistent in part with the prescriptions for sustainable development advanced by Norgaard, Glaeser, Redclift, and others.

A proactive stance is not necessarily innate to a cumulative effects perspective - traditional approaches to environmental management might also be set within a more strategic and integrated development framework. The cumulative effects perspective adds some important dimensions that give greater substance to environmental impact assessment, however. The cumulative effects approach described in Figure 1 requires direct consideration of human activities (for example, projects) in the context of other developments and activities. The framework also presents a call for environmental assessment to move away from what Norgaard called the atomistic-mechanistic approaches to knowledge -- non-linear environmental process responses and feedback mechanisms that impact upon the entire environment (social, economic, biophysical) are incorporated, for example.

In the absence of some reference to an appropriate institutional setting, none of this has real integrity nor consistency in terms of the aforementioned prescriptions for sustainable development. In short, to be effective, cumulative effects assessment must move beyond the project focus that has characterised EIA, and become a central part of regional development planning. Only in this institutional context can the important interactions amongst disparate activities, those amongst development priorities, and the nature of ecological response characteristics be captured with effect.

The advantages of a regional/ecosystem focus to environmental management have been recognised for some time (for example, Cooper and Zedler 1980; Beanlands and Duinker 1983), although the necessary institutional responses have generally not been forthcoming. With reference to cumulative effects in particular, Contant and Wiggins (1991: 307) remarked recently: “At the heart of most of these suggested efforts is an attempt to resolve the mismatch that is often present between the level at which cumulative impact occurs and the jurisdiction through which control efforts can be exercised… Therefore, adequate control of cumulative impacts requires regional planning and cooperation”.

Rees (1988) also has argued that environmental management should be organised at a regional scale. Rees’ article is especially relevant to the present argument, since he links regionally-based cumulative effects assessments and sustainable development. For example: “A major force behind the call for sustainable development is concern about the cumulative environmental and social effects of human activity at all spatial scales” (Rees 1988: 284). Rees then proceeds to argue that effective management of cumulative effects and planning for sustainability is best carried out at a regional scale, with regional planning units defined according to ecological criteria. Regional carrying capacity estimates are essential, Rees argues, since these could provide the basis for evaluating the significance of cumulative effects. Moreover: “An understanding of carrying capacity provides a functional definition of sustainable development” (Rees 1988: 285).

The necessary institutional reform will perhaps not come easily. At the 1985 joint Canada-U.S. workshop it was observed that: “The assessment of cumulative effects directly challenges these entrenched practices, jurisdictions, and value systems, and so will not easily be accommodated within the established mechanisms” (Roots 1986: 152). In New Zealand, an ideal opportunity was presented in the late 1980s, at which time parallel reforms of territorial local government and environmental management laws were initiated. The outcomes offer some basis for optimism. The reform of environmental legislation has given rise to a single piece of legislation that purportedly provides an integrated basis for resources and environmental management. The first principle of the Resource Management Act 1991 is sustainable management. The Act also confers primary responsibility for resources and environmental management upon 14 regional councils, established under the reform of local government (Local Government Act 1989). In these reforms the basis for effective environmental management along the lines suggested above is established. Whether the interpretations and practice of environmental management will extend to the ideas expressed by Norgaard, Glaeser, Redclift and others is...
The Assessment of Cumulative Environmental Effects

Not unexpectedly, the recent focus on the interpretation of environmental change from a cumulative effects perspective has been accompanied by an interest in the methods that might be used for the assessment of cumulative change (CEARC 1988; Cocklin 1989; Cocklin et al. 1992b; Contant and Wiggins 1991; Dames and Moore 1981). It is fair to say that progress in this respect has been limited, however. This is understandable, given three characteristics of the cumulative effects perspective.

1. The nature of environmental change. Descriptions of cumulative environmental change have helped to reinforce the understanding that the responses of the environment to perturbations often follow complex pathways of stress-process-response, which are frequently non-linear. While this fact has long been known to environmental scientists, in environmental impact assessments simple cause-effect sequences are often assumed. By accepting the greater complexity of environmental change that is central to the cumulative effects perspective, a significant challenge to the methodology of environmental assessment then looms. The linked stresses of multiple human activities must be acknowledged in the analysis, as must the diverse processes of environmental change itself (for example, synergistic effects, bioaccumulation, compounding, etc.). A further challenge to methodology lies in linking known (cumulative) stresses to identifiable impacts.

2. Extended spatial boundaries. Whatever approach is taken to cumulative effects assessment (for example, a project focus or the regional/ecosystem approach), an expansion in the spatial frame of reference (relative to conventional EIA) follows inevitably. Many of the methods of evaluation that have been used in EIA have been aspatial. While this has been identified as a shortcoming of the respective methods, the limitation takes on greater significance in the context of CEA, especially if the regional approach that has been advocated here is adhered to.

3. Extended temporal boundaries. Similar observations to those immediately above follow with respect to temporal boundaries. The cumulative effects perspective will have the tendency to expand the time frame that is assumed in environmental assessments. Evaluation methods that have been used for EIA traditionally are defined poorly in the temporal dimension, and this leads to doubts as their utility in respect of CEA.

In addition to these generic problems, if the regional/ecosystem approach to CEA is followed, further difficulties may ensue. In a conventional EIA a specific, identifiable action is presumed and the analyst then seeks to assess the likely consequences in terms of the environment. Methods of evaluation have been developed accordingly. The regional approach to CEA is less clearly focused, however, assuming more the characteristics of development planning within an expanded frame of reference (especially in terms of the environment). Hence, a regionally-based CEA is going to require wide-ranging, exploratory approaches to environmental assessment.

Below, selected methods of environmental assessment are reviewed in respect of their suitability for CEA and in light of the comments above. This short review helps to underscore some of the methodological problems that beset CEA currently, more than it works explicitly towards the identification of suitable methods of assessment. The list of methods was developed with reference to those that have recently been cited in association with CEA.

Environmental Indicators

There has been some reference to the use of environmental indicators in the context of CEA (for example, Orians 1986; Regier 1986). The main purpose served by these indicators would be to identify the presence, and perhaps the nature, of cumulative stress. Although there has traditionally been a greater emphasis on the use of chemical indicators in environmental management, since regulatory standards are more commonly expressed as concentrations of chemicals rather than in terms of their effects upon biological systems, the use of biological indicators appears to have found wider support in respect of cumulative effects. Orians (1986: 5) observed: "...there are strong reasons for using living organisms to tell us whether or not the standards established as a result of these experiments (re. chemical inputs) are really appropriate in the more complex and variable field conditions to which they are actually intended to apply". As Orians also notes, though: "How do we decide the value of using unusually sensitive species, accumulator species that may be relatively resistant to chemicals, or mixes of species so that competitive and predator-prey interactions are part of the monitoring program?".

More substantive reviews of the alternative types of environmental indicators (for example, indicator species, life history studies, distress syndromes) are presented by Cairns (1986), Cocklin et al. (1992b), Dayton (1986), Regier (1986) and Friend and Rapport (1989). Important observations within this literature refer to the need to improve the diagnostic capabilities of these indicators (that is, in identifying the sources and nature of cumulative stress), the
need to develop indicators that provide earlier signals of stress, and a requirement for methods that provide a better basis on which to predict change, based on known cause-effect relationships.

Environmental Impact Assessment Matrices

Since the development of the Leopold Matrix in the early 1970s (Leopold et al. 1971), an array of methods similar in structure and intent have been designed (for a review, see Shopley and Fuggle 1984). These EIA matrices have since become a standard method within EIA, providing a capability to summarise, and sometimes evaluate, environmental impacts.

EIA matrices are typically rectangular in their format, with a listing of project activities on one axis and anticipated environmental impacts on the other. Through this simple structure, there is an effort to represent the respective linkages between project activities and environmental impacts (that is, cause and effect). Relationships between project activities and environmental impacts are variably represented either quantitatively or qualitatively within these matrices. Given the widespread use of these matrices in EIA, their relevance to the assessment of cumulative effects merits review. Two main observations are offered here:

1. the EIA matrix format does not provide an adequate facility through which to portray the complexity of cumulative stress-process-response sequences;
2. EIA matrices provide poor resolution in the spatial and temporal dimensions.

One environmental matrix structure of more recent origin promises greater relevance to CEA. The structure was originally designed by Clark (1986) for the purpose of representing the effects of human activities on the atmospheric environment. An adaptation of the method was presented in Cocklin et al. (1992b) as one part of an analytical framework for CEA and this is reproduced here as Figure 2. The upper left quadrant of the matrix pairs human activities with measurable changes in the environment. In the lower left quadrant, interactions within environmental systems are indicated (for example, synergistic effects, compounding, accumulation, etc.). Measured changes in environmental parameters are then related to more general indicators representing valued attributes of the environment (the lower right quadrant). At the fourth step (the upper right quadrant), changes in the valued environmental components are related back to the human activities that are the sources of change.

This is a structure that has some heuristic value, in the sense that it captures, with much better effect, the nature and complexity of the sequence of...
stress-process-response. In this respect, it is a significant improvement upon other matrix methods of a similar kind. The relevance of the matrix in applied contexts will be compromised severely by the ability to quantify the components of the matrix; the environmental process quadrant (lower left) may be especially problematic. Note should also be taken of the fact that this structure has no spatial or temporal dimensions, a characteristic common to most EIA matrices.

Environmental Input-Output Models

In the late 1960s and early 1970s, extensions to the traditional economic input-output structure were proposed with the objective of expressing in quantitative terms the linkages between economic activity and the environment (for a review of these models, see Lonergan and Cocklin 1985). Recently, James and Boer (1988) have promoted the use of input-output techniques in respect of the analysis of cumulative environmental effects:

"There is clearly a need for environmental assessments that are process oriented and which capture regional and cumulative effects... Secondary economic and cumulative environmental impacts are most conveniently analyzed by means of multisectoral or input-output models".

This overstates the possible contribution of input-output models to cumulative effects assessment. Although several of the models that incorporate environmental "sectors" are useful conceptualisations of the economy-environment linkages, few have ever achieved operational status. Data limitations, structural features of the models (for example, linear functions) and the inability to specify certain components of the models, notably the environmental process matrices, have meant that it has not been possible to model environmental effects with the same effect that input-output models have been used to estimate economy-wide industry impacts.

Geographical Information Systems

Geographical information systems (GIS) have found support and some application in association with CEA. Manning (1990) attested to the relevance of GIS in respect of planning for sustainable development:

"Sustainable development is meant to imply a more holistic approach to the inter-relationships of the environment and the economy. The objective is to better inter-relate the many variables which will affect the long-term success of our economy, our society and our biosphere. Geographic information systems are about integration and are therefore a natural tool to serve in dealing with sustainable development".

There is a strong parallel between what this statement implies and the regional approach to CEA. Manning goes on to describe the use of GIS to evaluate resource capability vis-à-vis changing use patterns, the integration of economic and biophysical information, decision support for specific projects, and the modelling of alternative futures under the precept "anticipate and prevent", all of which are essential to planning for sustainable development and all of which have a place in CEA.

More directly, Johnston et al. (1988: 1609) said: "Geographic Information Systems provide a practical means of conducting CI (cumulative impact) assessments because of their capability to compile, process, and evaluate data collected over a long time period and for a large geographic area".

The application of a GIS in association with a regional CEA is reported in Cocklin et al. (1992b). Five types of analysis are described there:

1. the assessment of the effects of a single activity upon a single environmental attribute;
2. an assessment of the effects of a single activity upon multiple environmental attributes;
3. an assessment of the effects of multiple activities upon a single environmental attribute;
4. the assessment of the effects of multiple activities upon multiple environmental attributes; and,
5. project assessment.

There are several advantages that GIS offers in the context of CEA, especially if the assessment is regional in its scope. The primary advantage lies in the capability of GIS systems to store, order and report large quantities of spatially-referenced data. Specific capabilities inherent to GIS systems, such as the ability to overlay data coverages and to calculate various spatial statistics, are also of use in the context of environmental analysis.

What GIS does not provide, however, is any innate capacity to represent the nature of environmental change (that is, stress-process-response). While relevant process models might be incorporated within a GIS, these need to be developed exogenously and then imported to the GIS. If suitable process models can be developed and linked to a GIS, with its capabilities for both spatial and temporal definition, then some progress towards an analytical framework of use for CEA might be made.
Priorities in the Development of Methods for CEA

The development of appropriate methodology in respect of CEA is not well advanced, as this short review is intended to convey. There is no intent here to endorse any specific approach to methodology, but the following general observations are offered.

1. By its nature, CEA demands methodological pluralism. It is unlikely that there will be any "one-step" method that will be adequate for the task of representing and evaluating cumulative impacts. Integrated analytical frameworks, that draw upon several individual methods, perhaps offer the greatest promise.

2. Much of the effort in developing appropriate methodology should go towards the identification of frameworks that will assist in defining, representing, predicting and evaluating the causal sequences of environmental change (that is, stress-process-response).

3. Assuming some progress is made in respect of 2., GIS offers some useful capabilities, especially in respect of the ability to represent the spatial and temporal dimensions of change within the context of a regionally based CEA.

Cumulative Effects and Sustainable Development

In this paper those expressions of the concept of sustainable development that emphasise an holistic, integrated perspective -- those that acknowledge the interconnections among systems of production and exchange, social and political structures, the bases of knowledge and science, and the biophysical environment -- have been endorsed. In addition, an interpretation of cumulative environmental change and its assessment has been presented. The paper in its fullness represents a claim to the effect that sustainable development and cumulative effects and their assessment are somehow related; it now behooves the author to confirm this more explicitly. Towards this, three specific observations are proffered.

1. The cumulative effects perspective assumes a broad frame of reference for describing and assessing the effects of human activity in terms of the environment. In particular, we acknowledge: (a) the accumulation of stresses upon the environment, often originating from disparate sources, and; (b) the myriad responses that follow from the various sources of disturbance.

2. Following more or less directly from 1., the cumulative effects perspective on environmental change provides direct reference to the complexity of stress-process-response sequences, which often involve feedbacks and other non-linear relationships. This provides at least a tentative step away from the reductionist approaches to environmental assessment that have prevailed. In doing so, there is a direct consistency with the views of Norgaard, Glaeser, Redclift and others in respect of the epistemological foundations of our analysis.

3. The concept of cumulative effects assessment that has been expressed here emphasises both a regional and a proactive approach. In the first characteristic (regional), the holistic/integrated perspective is consolidated (see 1.). In adopting an approach to environmental assessment and management that is both regional and proactive, the potential to go beyond what Redclift has called "environmental managerialism" is presented.

Conclusions

To state that these are part of the reality of human-induced environmental change is a truism, even though EIA has not usually been practised in accordance with these observations. With the effects of human activity being central to our concern for sustainable development, the cumulative effects perspective offers not only a conceptual framework for describing aspects of human/environment interaction, but also a framework for assessment. Challenges to sustainability, then, can be expressed in terms of the cumulative effects of human activity.

In these three characteristics, the consistency that cumulative effects and their assessment have with the views of some people in respect of sustainable development is evident. Not only does the cumulative effects perspective present a framework within which to articulate in part the dimensions of sustainability (that is, in respect of some aspects of human/environment interactions), but applied cumulative effects assessment could provide one basis for the measurement of progress towards, or departure from, a sustainable development path.

The notion of cumulative environmental change and its assessment are important, since they provide a possible framework within which to broaden the basis for environmental management. The interpretation of CEC outlined above offers the promise of a constructive advance upon the managerialist tradition.
This concept of cumulative change and its assessment is consistent with sustainable regional development. Interest in sustainable development itself is, in large part, a product of concerns over cumulative changes to the environment. The notion of cumulative change offers a framework within which to describe and analyze with greater accuracy the complex nature of environmental change. The prescription advanced here is consistent with the views of Norgaard and others in that it presumes a holistic view of the forces precipitating change and the consequent need to consider, in broad and integrated terms, the effects of change.

A considerable amount of work remains to be done in respect of the development of suitable methods for CEA, however. Reference has been made in the literature on cumulative effects to several methods of analysis but, as the short review here suggests, none of these are well suited to the task. The useful developments in this respect will come, quite possibly, from integrated analytical frameworks which embody stress, process and response and which give adequate expression to the spatial and temporal dimensions of change.

It is appropriate to end on a note of caution, however. The assessment and management of cumulative effects presents a conceptual and methodological framework within which to give effect to sustainable regional development. While the adoption of a cumulative effects perspective may be a necessary condition for sustainable development, at least in the sense that prevailing environmental management approaches are patently inadequate, it is certainly not a sufficient condition. To give effect to sustainable regional development in the sense that has been promoted here requires that we overcome the ontological separation of the natural environment from human development, which is so deeply rooted in Western philosophical traditions. At the practical level, this means that there must be a fundamental re-balancing of objectives. Since this will challenge many entrenched interests, progress will not be easy.

References


