A CONCEPTUAL SYSTEM MODELING APPROACH TO ECOLOGICAL INTEGRITY PLANNING: A CASE STUDY OF THE GREATER KLUANE REGION, YUKON

Brent H. Parker
Department of Geography and Environmental Studies,
Wilfrid Laurier University

Abstract

Fundamental to maintaining the integrity of protected area ecosystems is understanding their complexity and ecological organization within the context of their bioregional surroundings. This research sets out a conceptual system model to synthesize knowledge from diverse fields and identify key ecosystem processes, thereby providing new insight into system organization, function, and integrity (Parker, 2003). This understanding was then applied to planning for ecological integrity in the Canadian National Parks context through a case study of the Greater Kluane Region (GKR), Yukon, an area encompassing Kluane National Park and Reserve (KNP&R). A set of criteria, derived from complex systems and hierarchy theory served as the basis for identifying key processes in the GKR. A panarchy model (Gunderson and Holling, 2002) was used to integrate these key biophysical and socioeconomic processes, describe their role(s) in system stability and resilience, and elucidate pathways by which significant ecological change may occur. The case study of the GKR illustrates the heuristic value of a conceptual modeling approach and its import in building a synthetic and adaptive knowledge base to found ecological integrity planning.

The Challenge of Ecological Integrity

With the continuing search for a holistic theory of environmental management ecological integrity is receiving increased attention, and becoming a leading concept in environmental management strategies (Norton, 1992; Woodley *et al.*, 1993). In 1988 ecological integrity was established as the first priority in Canada's national parks, while more recently it has gained increased prominence as a result of the 2000 report released by the Panel on the Ecological Integrity of Canada's National Parks, the main message of which was that this mandate is in peril. As defined by Parks Canada (Parks Canada, 2000) *"An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes"*. This definition provides a normative goal for parks within the national system. The challenges of interpretation, appropriate policy development and on-the-ground application remain.

Ecological integrity is a plastic concept dependent on the scale at which it is applied and the conceptual perspective(s) underlying its application (King, 1993). Applying the concept of ecological integrity through planning, management and assessment necessitates a holistic understanding of ecosystem organization and function. However, managing for ecological integrity often rests on analyses that only partially integrate ecosystem complexity and generate results with limited ecological relevance (Schaeffer *et al.*, 1988). A much greater understanding is needed of the relationship between ecosystem structure and function across hierarchical levels. At larger scales of research the integration of knowledge from many disciplines is vital but lacking (Brown, 1994). There is a concurrent need to identify coupled feedback cycles that may lead to synergistic or large-scale effects on ecosystems when affected by human activity (Jefferies and Bryant, 1995).

Confounding the development of such fundamental understanding to guide ecological integrity planning is the inherent complexity of ecosystems, the segregation of knowledge perpetuated by disciplinary study, and the construing of hierarchical organization in ecological systems as being spatially nested (Allen and Hoekstra, 1992). A synthesis of empirical knowledge founded by a robust conceptual base and integrated across scalar domains is needed if we are to effectively develop policy and management practices that nurture ecological integrity.

Fostering Synthesis While Maintaining Pluralism

The difficulty in the realm of ecology arises in dealing with the interplay of processes operating at different rates or scales that produce complex interactions and patterns. Over time as the complexity of a system's organization and interactions increase so too does the intractability of its behaviour. This scalar disparity and complexity, combined with our tradition of scientific reductionism, has resulted in an array of disciplinary studies (e.g., microbiology, physiology, population biology, ecology, landscape ecology, community ecology), the outcome of which has been disparate bodies of knowledge (Allen and Hoekstra, 1992). Just as the notion of observational scale affects ecological description of organization, function and integrity so too does ones conceptual perspective. Describing the integrity of ecological phenomena requires synthesis of the knowledge accumulated from diverse scientific as well as experiential traditions. In seeking a holistic understanding of integrity employing a pluralistic approach that draws on a diverse array of conceptual perspectives will enrich system description and subsequent understanding. Table 1 outlines six rich concepts drawn from pendant fields that facilitate different ways of observing ecological phenomena across many scales (Allen and Hoekstra, 1992). Diverse but convergent research perspectives/efforts are essential, as a pluralistic approach is needed to describe complex systems. Employing these in a system description provides a means to garner complementary insight into a system's ecological organization and function.

A Conceptual Framework: Complex Systems Thinking and Hierarchy Theory

Complex systems thinking is increasingly being employed to engender integrative, holistic perspectives and approaches to describe ecosystem dynamics (Jorgenson and Muller, 2000). A systems approach may prove effective in linking the diverse perspectives outlined above (and underlying theory) into a coherent whole. The rationale of systems thinking is that a system, such as an ecosystem, cannot be understood by teasing it apart and studying the parts in isolation. Understanding must be derived from a holistic systemic investigation because there are properties of the system and its parts that emerge from the ordered relationships within the system (Bertalanffy, 1968).

Table 1. *Conceptual perspectives and attendant criteria used to characterize system processes.*

CONCEPTUAL PERSPECTIVE	CRITERIA USED TO CHARACTERIZE SYSTEM PROCESSES
Global	Critical climate, physiography and vegetation physiognomy; gradients over large areas
Landscape	Spatial areas, contiguity, and patterns; fluxes of materials in spatial contexts; topographic relations
Ecosystem	Sequences of events rather than spatially located; energy and matter movements; pathways of processes and fluxes between organisms and environment; interlinked, scaled processes defined in turnover times
Community	Integration of complex behaviour of biota; accommodation between organisms; members who share a common resource; not a function of the environment but rather exhibit a relation to the environment
Population	Collection of individuals with genetic relatedness bound together by interactions; predator-prey pairings stem from the population concept
Organism	Genetic integrity, discrete bodily form, physiological integrity and autonomy; a collection of fluxing internal processes with a tangible boundary; the functional environment as defined by an organism's perceptual boundaries is of particular interest in linking to other conceptual domains

Living systems have been described as dissipative structures, which by dissipating exergy as entropy to their surroundings maintain a high degree of order i.e., organization (Wicken, 1987). Organization as such can be described as perpetual reorganization produced by degradation and regeneration of the system (Morin, 1992). It is the continual processing of energy, and the resultant structure, that enables ecological systems to dynamically respond to environmental change. A system's continued integrity is contingent on this dynamic self-organizational capacity to avoid becoming maladaptive and catastrophically vulnerable to novel change. It is from this basis that catastrophic events such as fire, flooding, and drought, are understood to be important elements in the natural renewal, reorganization and evolution of ecosystems. Such disturbances may cause an ecosystem to proceed through a period of rapid reorganization to a steady state with new dissipative structures, i.e., new energy pathways between old parts or new pathways emerging from the presence of new component parts (Kay *et al.*, 1999). This new state may be quite different from the former state of the system. If, for example, prolonge flooding occurs in an area the attendant anaerobic conditions will suppress the microbia community. This suppression induces nitrogen loss, limits and protracts decomposition and results in nutrient-limited soil (Freedman, 1998). Under such changed conditions nev successional trajectories often ensue. Such disturbances not only change the present stat of the system but by their cascading influence on process pathways alter conditions suc that former states are excluded.

Historically, an equilibrium-centered view where populations and succession progress along a linear path to a stable equilibrium state has directed investigations of ecosystems (Jensen *et al.,* 2001). The more recent resiliency-based view (Holling, 1973) acknowledges the inherent variability, heterogeneity, complexity and subsequent unpredictability of living systems. Holling's (1973) now classic adaptive cycle model of ecosystem dynamics describes four phases in ecosystem development: exploitation, conservation, release and reorganization (Figure 1). Instability in response to changing variables is seen as maintaining the system's resilience by enabling reorganization and adaptation to future change (Gunderson *et al.,* 2000). Such an understanding suggests management be directed at maintaining the innate resilience of systems to ensure their capacity to absorb environmental change (Gunderson and Holling, 2002).

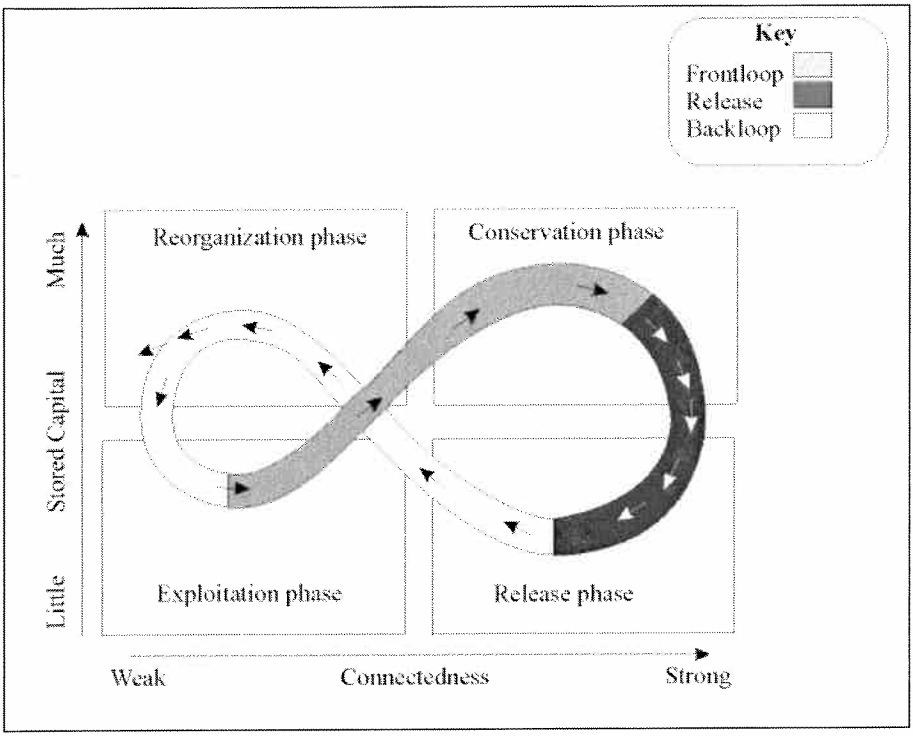
Succession occurs from the exploitation phase to the conservation phase at which point overconnectedness and abundant natural capital precipitate a catastrophic disturbance. Such disturbances release stored capital and reduce the connectedness of ecosystem processes and in so doing make resources (e.g., carbon and nutrients) accessible for reorganization into another adaptive cycle. The arrows relate to the speed of the adaptive cycle with closely spaced arrows indicating rapid change. The arrows moving outside the figure eight in the reorganization phase depict the potential for leakage of capital (e.g., nutrients) and subsequently novel reorganization (Figure 1).

The importance of scales in ecosystems is being made more explicit through the application of hierarchy theory in ecology (King, 1993). Natural systems have been described as consisting of a hierarchy of ordered relationships. This view asserts that higher levels (larger spatiotemporal scale processes) constrain those below providing context and boundaries for their activity, while lower levels are basis for the emergence of upper level phenomena.

Knowledge of the scalar organization of ecological systems is particularly useful in conceptualizing organization and integrity in complex systems. Complexity is a feature of natural systems arising in part from the occurrence of processes at different rates of speed, differently scaled structures and/or entities of disparate types. The notion of hierarchical levels in systems provides a general organizational frame with which to investigate and characterize complex system interactions (Figure 2) (Allen and Hoekstra, 1992).

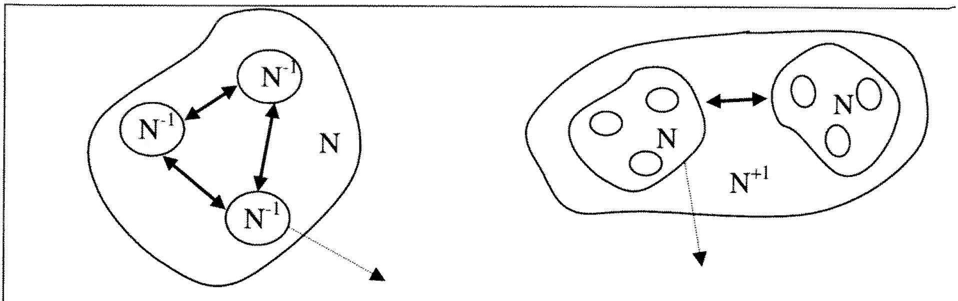
Returning to the adaptive cycle described by Holling this phenomenon operates across hierarchies from small to large scales (Gunderson *et al.,* 2000). This dynamic interaction of adaptive cycles has been coined a "panarchy", a term that is synonymous with hierarchies. Panarchies are essentially made up of a nested set of adaptive cycles that exhibit multiple cross-scalar connections between levels. These cross-scale interactions are particularly important during release and reorganization phases. During the release phase of lower level adaptive cycles disturbances may cascade up to higher levels and precipitate a catastrophe (Figure 3). Conversely, following a catastrophe the potential stored during the conservation phase of larger slower upper levels determines the constraints and opportunities for lower level reorganizations.

Figure 1. *Figure-eight model of the adaptive cycle of ecosystem dynamics.*



Central to understanding ecological integrity is elucidating pathways of change and transformation in ecosystems. Conceptualizing ecological systems as dynamic self-organizing complexes made up of hierarchies of adaptive cycles (i.e., panarchy) provides a starting place for describing key processes driving ecological organization and exploring how biophysical and socioeconomic interrelationships impact on ecosystems. In this endeavor the cross-scale interactions of processes are used to elucidate connections and potential pathways of change. Through their highly integrative functioning key processes link across conceptual domains and scales (e.g., succession links an array of communities with ecosystem development while functional structures such as functional species groups tie organisms to ecosystem processes). Process interactions that alter system feedbacks and engender new pathways for ecosystem development are of particular interest. Such a conceptual systems modeling approach describing process pathways to change was developed for the Greater Kluane Region (GKR) in the Yukon to elucidate how impacts might propagate throughout regional ecosystems and affect ecological resilience and integrity within Kluane National Park and Region (KNP&R).

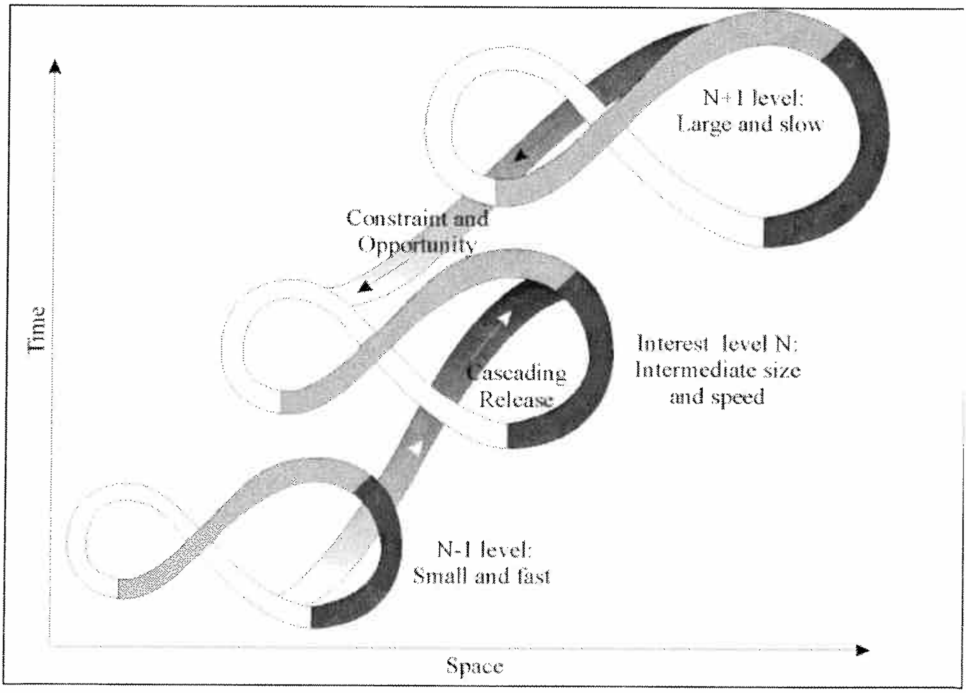
***Figure 2.** A depiction of hierarchical levels and their interactions across system boundaries.*



N is bounded as the holon of interest based on strong internal connections (processes) between lower level holons indicated as N^{-1}, and weak external connections beyond the boundary.

Focusing up a level from N to N^{+1} the weak connections exhibited by N^{-1} to the outside world become the strong connections of N that define level N^{+1}.

***Figure 3.** Panarchy model showing cross-scalar connections of adaptive cycles.*



Case Study Overview: The Greater Kluane Region

Located in the southwest corner of the Yukon, the GKR an area (66,000 km^2) encompassing KNP&R and many of the human activities that influence it served as a case study for applying the conceptual system model. Although extensive information on the ecology of the region exists much of it remains unsynthesized while conceptual models of ecological integrity in KNP&R, and in general, are relatively simple (Schaeffer *et al.*, 1988; Parks Canada, 2001).

Due to its remoteness from major human settlement and size, 22,013 km^2, KNP&R has effectively conserved a large intact wilderness area where ecological processes dominate. However maintaining the park's wilderness character is not without its challenges. The introduction of exotic species, unforeseeable management effects, and outside human activity such as mining, dams, agriculture, sewage disposal, sport fishing, and urbanization have been identified as causing significant ecological impacts, while new and expanding developments in the region including tourism, forestry, and mining have the potential to compound these stressors (Parks Canada, 2001; Slocombe *et al.*, 2002).

Identifying Key Organizing Processes

After identifying a wide array of processes through literature review and regional consultations, three criteria distilled from the preceding discussion of complex systems were used to assess and identify those that were key in the GKR:

- Domain of influence: characterized ecosystem processes according to conceptual perspective (Table 1) best suited for observing role/influence of process and then delimited functional scale of action;
- Relatedness: identified and compared influence, on and by, each process to assess the role in system connectedness; and,
- Cross-scale interaction: located processes within the adaptive cycle to determine how each was associated with phases of ecosystem development (i.e., frontloop, release phase, backloop or environmental context) (Figure 1).

As the functional agents integrating many ecosystem processes across domains, species were characterized using a functional groups approach (Chapin *et al.*, 1995). Flora and fauna in the GKR were classified according to their influence on resource supply and cycling i.e., nutrients. Using the assessment criteria 28 highly integrated processes were delimited for inclusion in modeling (Figure 4).

Modeling System Organization and Function

The GKR panarchy model depicts the association of key processes with adaptive cycles across the six conceptual domains (organism, population, community, ecosystem, landscape, global) and portrays their role in system stability or resilience. The central foci of each domain is depicted at right (*) along with those species that are particularly significant because of their ecology (i.e., influence and or vulnerability) (Figure 4).

Socio-economic Interactions

With the panarchy model serving as a template of ecosystem organization and function, focus turned to exploring the influence of socioeconomic processes. During this step it was important to assess the linkages between socioeconomic and regional ecological processes in order to describe how human-induced activity might propagate throughout the system. The socioeconomic processes with the potential for the largest influence are those in the global domain and include climate change and the long-range transport of pollution. However, more direct and immediate effects at the landscape and ecosystem level will likely be felt through regional activities including cumulative impacts from recreational activities, mining, fire management, and forestry. Exotic species are of concern, although their threat has not been assessed in detail, while wildlife management in the GKR is occurring with limited monitoring or assessment of its ecological effects.

Process Pathways to Change

Linking up the understanding of system dynamics engendered by the conceptual model with a knowledge of significant human impacts in the GKR potential process pathways to change could be described. Table 2 provides three examples of the potential pathways through which human influence could affect significant system change in the GKR (Parker, 2003 provides a thorough discussion of socioeconomic influences).

Figure 4. *Panarchy model depicting associations among adaptive cycles, key processes and species in the GKR .*

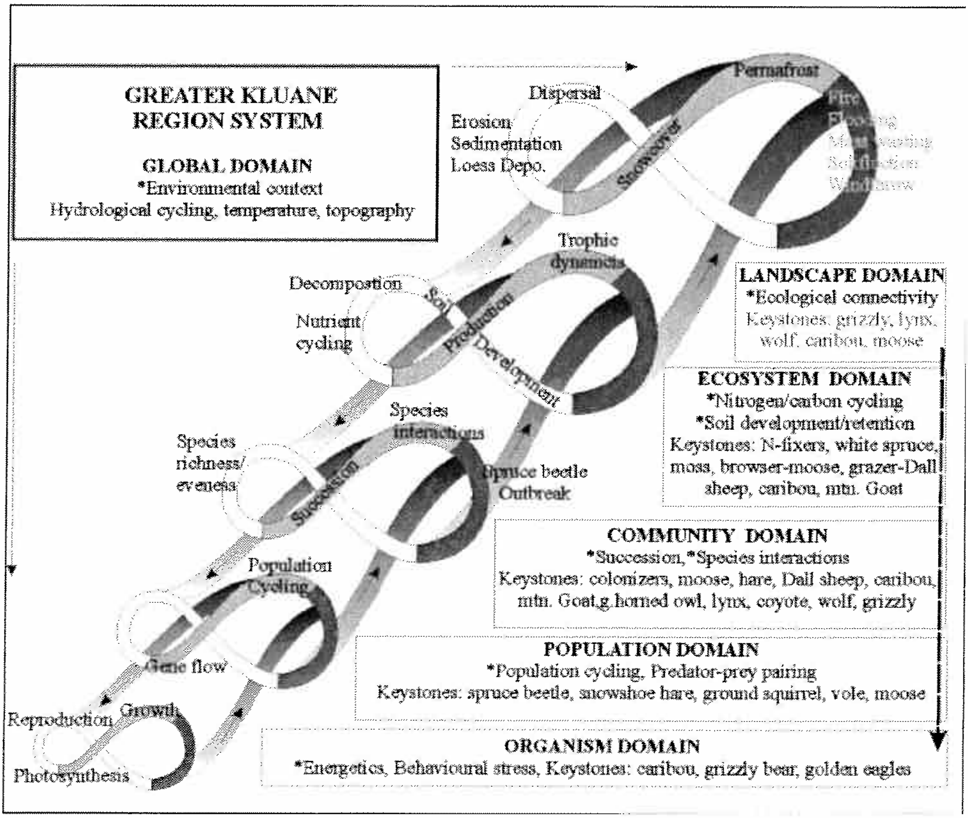


Table 2. *Illustrative examples of Process Pathways to Change triggerd by Socioeconomic influences in the GKR.*

SOCIOECONOMIC INFLUENCE	PROCESS PATHWAYS
Global level Large anticipated human -exacerbated climatic changes in the GKR.	Drought influence on fluvial, fire and insect disturbance regimes with likely alteration of disturbance regimes creating prime conditions for insect infestations .
Landscape level Fire and forestry management as well as climatic change may precipitate changes in fire regime.	Synergistic influence of fire regime patterning on insect outbreaks will have attendant effects on insect outbreaks.
Community level Wildlife management activities .	Associations between flora -fauna entrain particular successional pathways; alterations of wildlife populations/keystone species during reorganization and exploitation phases may have significant trophic and or succession effects .

Addressing questions about impacts on ecological integrity from a process pathway basis serves to elucidate the larger systemic interactions in relation to the specific issue being addressed thereby helping in holistic problem framing of management issues. The model suggests some general tenets for describing and understanding system change:

- the larger, more frequent, more intense or the more types of environmental change occurring simultaneously the greater the potential for novel system reorganization;
- due to the cyclic nature of system processes, the impact of environmental change varies according to the cyclic period in which it occurs; and,
- system heterogeneity, redundancy, and modularity all act to limit the influence of environmental changes.

Implications for Ecological Integrity Planning and Management

Presently, ecosystem models developed by KNP&R, as well as those in other national parks, serve to facilitate the selection of indicators for monitoring, although their role will hopefully expand as Parks Canada's renewed focus on ecological integrity takes hold. A robust model such as the one developed in this research could serve an expanded heuristic role in informing planning and management action.

A Synthetic and Adaptive Knowledge Base

Parks Canada, as an agency, currently undervalues the benefits of learning, providing little guidance for incorporating new knowledge in planning and management (Parks Canada, 2000). This has impacts on the ability of managers to effectively apply an adaptive management approach (Parks Canada, 2001). The modeling process described here may serve as a synthetic and adaptive knowledge base, with which to better align the many components included in park management plans that are directed at maintaining ecological integrity. Such a knowledge repository used to familiarize planning participants with the agency's holistic approach to ecological integrity and to coalesce knowledge arising from planning processes would support the agency's commitment to adaptive management.

Linking Monitoring and Assessment to System Understanding

Monitoring is critical to assess ecological integrity, direct research, develop ecological understanding, detect change, and provide feedback on the effects of management action (Parks Canada, 2000). However, monitoring is not often well linked to management decision-making or accountability, and so has warranted limited attention. In light of the hierarchical structure of ecosystems, a monitoring program should identify the hierarchical context of monitoring protocols, in order to contextualize monitoring protocols and help in interpreting monitoring results. Applying the stratified design of the panarchy model to a monitoring program helps to establish the sensitivity of indicators and the extent and significance of changes detected by each.

Similarly, the typical valued ecosystem component (VEC) based cumulative effects assessment, normally applied in parks, would benefit from a more integrated understanding of ecosystem functioning, using conceptual models to augment present attempts to assess environmental impacts on ecological integrity. Such knowledge would enhance the pathway and network diagrams used in impact assessment (Hegmann *et al.*, 1999), minimize the likelihood of overlooking pathways by which socioeconomic activities may impact ecological integrity, and be a useful precursor for informing assessment and management goals.

Heuristic Stakeholder Engagement

There is widespread evidence that ecosystems cannot be protected without deliberately involving regional communities in planning and policy making (Mulrennan, 1997). Stakeholder engagement leading to partnerships is critical to maintain ecological integrity in KNP&R and elsewhere. A process of model-building similar to that employed in this research may be a useful process for park planners and managers to nurture a vision of ecological integrity amongst local communities, stakeholders, and other management agencies. Holding open, model-building workshops at parks would produce many benefits similar to those of the modeling carried out in this research, as well as elicit stakeholder values and knowledge, infuse planning and management with a systems understanding of ecological function, identify management concerns, and hopefully improve the base for cooperative partnerships. Through modeling, those involved in the process can build mutual understanding about a system and potential agreement on what management actions would be most effective (Costanza, 1996). It may be this heuristic value of such modeling that is most compelling.

Conclusion

The conceptual modeling process offers a rich approach for understanding complex regional systems such as that of the GKR and merits an expanded role in planning and management. Results indicate that ecological integrity planning would benefit by focusing on the dynamics of processes with cross-scale influence and employing keystone species as the tangible points of articulation between processes, conceptual perspectives, and scales. The dynamic hierarchical nature of ecosystems means that system description and management may be ineffective or even harmful if an equally dynamic and pluralistic approach is not taken. A conceptual model may serve as a synthetic and adaptive knowledge base with which to integrate new knowledge and cultivate system understanding to support ecological integrity planning. The heuristic process of developing region-specific conceptual models may help to foster the culture of learning in park agencies that is vital to managing for ecological integrity. It is an understanding of change, its origin, and process pathways of effects that should pervade planning, cumulative effects assessment, management, and monitoring for ecological integrity. It is hoped that new insight derived from this conceptual modeling perspective will empower management that might assure the protection of ecological integrity.

Acknowledgments

My thanks are first extended to those on my committee; Dr. Scott Slocombe for the academic freedom he encouraged; Dr. George Francis for his engaging discussion and meticulous review of my work; insightful reviews provided by Dr. Stephen Murphy and Dr. Kevin Hanna were instrumental in exploring the application of this work. This work would not have been possible without the support I received from the Parks Canada staff at Kluane National Park. I am also indebted to the staff at the Department of Indian Affairs and Northern Development (DIAND), Yukon Department of the Environment, Department of Energy, Mines and Resources, Yukon Archives, Yukon Tourism and the Champagne and Aishihik First Nation who so willingly contributed to my research. I thank Mike English for providing me with a wonderful space in which to work at the Cold Regions Research Center and the in-kind support along the way. This research was supported by the DIAND Northern Scientific Training Program, Wilfrid Laurier University, and a Social Sciences and Humanities Research Council Grant awarded to Dr. Scott Slocombe.

References

Allen, T.F.H. and T.W. Hoekstra. 1992. *Toward a Unified Ecology.* Columbia University Press: New York.

Bertalanffy, L. 1968. *General System Theory, Foundations, Development, Applications.* George Braziller: New York.

Brown, J.H. 1994. Grand challenges in scaling up environmental research. In: Michener, W.K., J.W. Brunt, and S.G. Stafford (eds.). *Environmental Information Management and Analysis: Ecosystem to Global Scales.* Taylor and Francis:

Bristol, PA. Pp. 21-26.

Chapin, F.S. III, S.E. Hobbie, M.S. Bret-Harte, and G. Bonan. 1995. Causes and consequences of plant functional diversity in arctic ecosystems. Pp. 225-237. In: Chapin, F.S. III and C. Korner (eds.). *Arctic and Alpine Biodiversity.* Vol. 113, Springer-Verlag, Berlin.

Costanza, R. 1996. Ecological economics: reintegrating the study of humans and nature. *Ecological Applications,* 6(4): 978-990.

Freedman, B. 1998. *Environmental Science, A Canadian Perspective.* Prentice Hall Canada: Scarborough, ON.

Gunderson, L.H., C.S. Holling, and G.D. Peterson. 2000. Resilience in ecological systems. Pp. 33-49. In: Jørgensen, S.E. and F. Müller (eds.). *Handbook of Ecosystem Theories and Management.* Lewis Publishers: Washington, D.C., U.S.A.

Gunderson, L.H. and C.S. Holling. 2002. *Panarchy-Understanding Transformations in Human and Natural Systems.* Island Press, Washington, D.C., U.S.A.

Hegmann, G., C. Cocklin, R. Creasey, S. Dupuis, A. Kennedy, L. Kingsley, W. Ross, H. Spaling and D. Stalker. 1999. *Cumulative Effects Assessment Practitioners Guide.* AXYS Environmental Consulting Ltd. and the CEA Working Group for the Canadian Environmental Assessment Agency: Hull, QC.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Revue of Ecology and Systematics,* 4: 1-23.

Jefferies, R.L. and J.P. Bryant. 1995. The plant-vertebrate herbivore interface in arctic ecosystems. Pp. 271-281. In: Chapin, F.S., III and C. Korner (eds.). *Arctic and Alpine Biodiversity.* Ecological Studies. Vol 113, Springer-Verlag: Berlin.

Jensen, M.E., N.L. Christensen, P.S. Bourgeron, 2001. An overview of ecological assessment principles and applications. Pp. 13-28. In: M.E. Jensen and P.S. Bourgeron (eds.). *A Guidebook for Integrated Ecological Assessments.* Springer: New York.

Jørgensen, S.E. and F. Müller. 2000. Ecosystems as complex systems. Pp. 5-20. In: Jørgensen, S.E. and F. Müller (eds.). *Handbook of Ecosystem Theories and Management.* Lewis Publishers: Washington D.C., U.S.A.

Kay, J.J., H.A. Regier, M. Boyle, and G. Francis. 1999. An ecosystem approach for sustainability: addressing the challenge of complexity. *Futures,* 31: 721-742.

King, A.W. 1993. Considerations of scale and hierarchy. Pp. 19-45. In: Woodley, S., J. Kay, and G. Francis (eds.). *Ecological Integrity and the Management of Ecosystems.* St.Lucie Press: Washington.

Morin, E. 1992. The concept of system and the paradigm of complexity. Pp. 125-138. In: M. Maruyama (ed.). *Context and Complexity Cultivating Contextual Understanding.* Springer-Verlag: New York.

Mulrennan. M.E. 1997. *A Casebook of Environmental Issues in Canada.* John Wiley and Sons Inc.: New York, U.S.A. 160pp.

Norton, B.G. 1992. A new paradigm for environmental management. Pp. 23-41. In: Costanza, R., B.G. Norton, and B.D. Haskell (eds.). *Ecosystem Health, New Goals for Environmental Management.* Island Press: Washington, D.C.

Parker, B. 2003. *Developing a Conceptual System Model for Ecological Integrity Planning, The Greater Kluane Region, Yukon.* Masters Thesis, Wilfrid Laurier University: Waterloo, Canada.

Parks Canada. 2000. *"Unimpaired for Future Generations?" Protecting Ecological Integrity with Canada's National parks Volume II: Setting a New Direction for Canada's National Parks.* Report of the Panel on the Ecological Integrity of Canada's National Parks: Ottawa, ON.

Parks Canada. 2001a. *First Priority-Progress Report on Implementation of the Recommendations of the Panel on the Ecological Integrity of Canada's National Parks.* Available: http://www2.parkscanada.gc.ca/library/first_priority/english.html#10e

Parks Canada. 2001b. *Kluane National Park and Reserve of Canada Management Plan.* Whitehorse, Yukon, 81pp.

Schaeffer, D.J., E.E. Herricks, and H.W. Kerster. 1988. Ecosystem health: I. measuring ecosystem health. *Environmental Management,* 12(4): 445-455.

Slocombe, D.S., R. K. Danby and J. Lenton. 2002. *Kluane National Park and Reserve CEA Update, Part 2 - Methodology and Assessment.* EDA Environment and Development Associates: Waterloo, Ontario, 128 pp.

Wicken, J.S. 1987. *Evolution, Thermodynamics, and Information: Extending the Darwinian Program.* Oxford University Press: Oxford.

Woodley, S., J.Kay, and G. Francis. 1993. *Ecological Integrity and the Management of Ecosystems.* St. Lucie Press: Washington.