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Synthesis, part of Special Feature on Sustainability and Resilience in Boreal Regions

Sustainable Development of the Boreal Forest: Interaction of Ecological, Social, and Business Feedbacks

F. Stuart Chapin[1] *and Gail Whiteman*[2]

[1]***University of Alaska-Fairbanks***; [2]***Queen's University***

ABSTRACT

Humans are an integral component of ecosystems, just as the products of ecosystems are critical to social systems. To understand the future state of the boreal forest, we must understand the ecological, social, economic, and business interactions that link ecological and social systems into a common regional system, as well as the feedbacks that govern changes in these interactions. We analyze the negative feedbacks that promoted a sustainable interaction between ecological and social systems prior to the development of business systems, which are dominated by positive feedbacks that have reduced the sustainability of the boreal system. We suggest a minimum set of interactions that are required to improve the sustainability of a business-based boreal system.

KEY WORDS: boreal forest, business, consumerism, ecosystem, feedback, social system, sustainability.

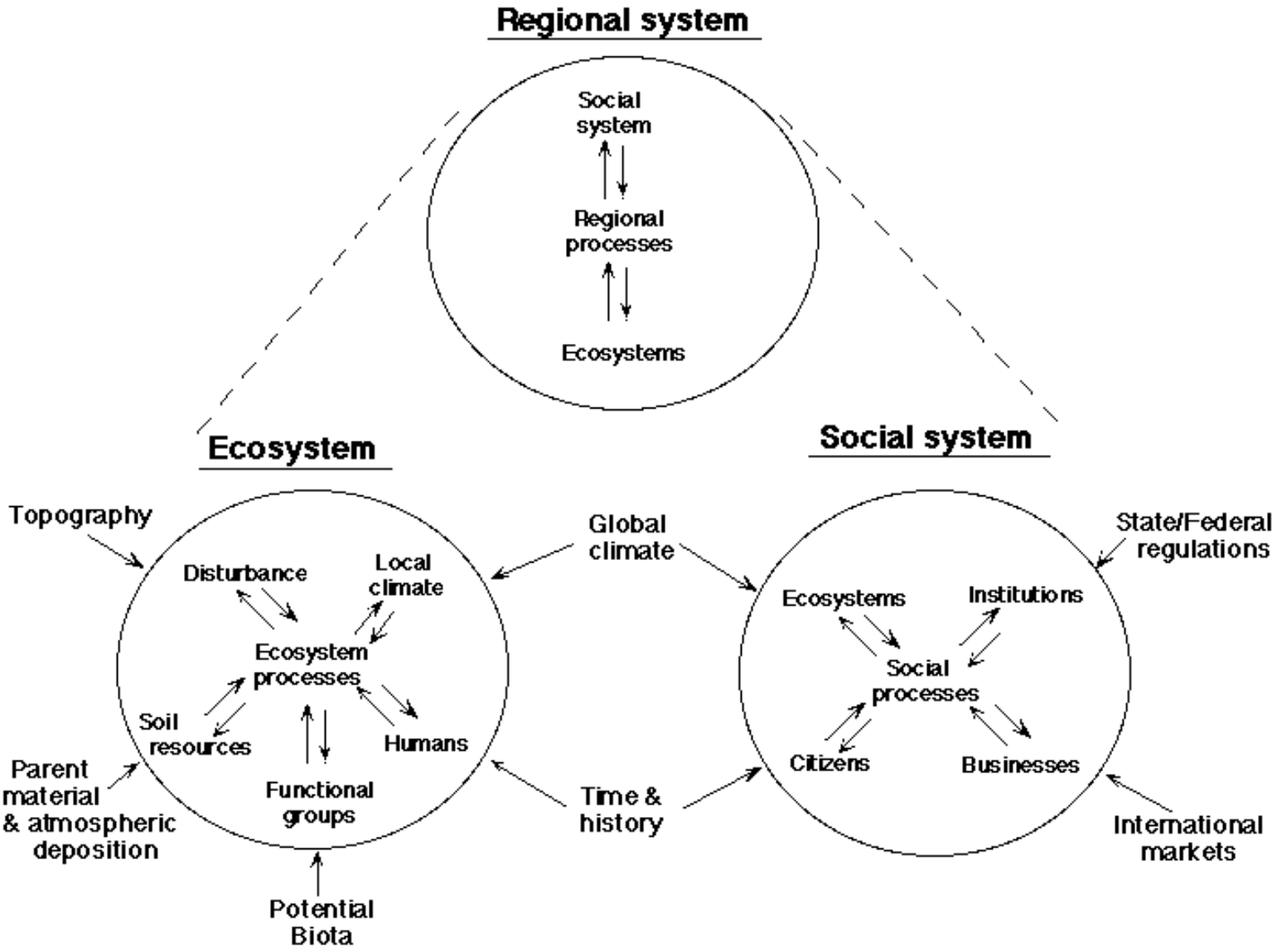
WHAT IS A SUSTAINABLE SYSTEM?

Any plausible scenario of the future states of either ecological or social systems must recognize their interdependence. Land use change is the component of global change that currently has greatest impact on ecological systems. Conversely, social systems are sensitive to the supply of renewable resources that provide food and fiber for human consumption and constitute the natural framework that underlies cultural systems. Thus, the first step in developing scenarios of a sustainable future of any region is to link ecological and social processes into a common conceptual framework. This article seeks to bring together perspectives that have been developed in ecology, social sciences, and business management into a common framework for predicting the future sustainability of the boreal forest. Although many of these principles have general applicability, we focus on boreal examples.

We define a sustainable system as one that maintains the same general structure, processes, interrelationships, and patterns of disturbance. It is convenient to define social systems and natural ecosystems separately because they differ in the relative importance of many of the controlling processes. However, it is increasingly clear that products of the natural environment strongly shape the functioning of social systems (Berkes and Folke 1994), and that human activities influence the activity of all natural ecosystems (Vitousek 1994). These interactions between the social and ecological systems must influence the long-term sustainability of each system. We also focus explicitly on business firms, because they are a component of the western social system that mediates many of the critical interactions between social and ecological systems. In this section, we suggest a framework within which to discuss the regional sustainability of the boreal forest, including its human residents, based on an understanding of the interactions within ecological and social systems.

The structure and functioning of ecosystems is determined by several factors that both affect, and are affected by, ecosystem processes. These factors (interactive controls) include regional climate, soil water and nutrient supply, the functional types of organisms present in the system, disturbance regime, and human activities (Fig. 1; see Chapin et al. 1996). For example, regional climate is affected not only by solar input and moisture supplies from oceans, but also by forest cover, which determines the amount of energy that is absorbed by the ecosystem and is available to heat the atmosphere (Bonan et al. 1992, Thomas and Rowntree 1992, Foley et al. 1994). Nutrient supply is affected not only by the types of rocks that give rise to soils, but also by the chemical composition and decomposition rates of leaf litter produced by different types of plants (Hobbie 1992) and by the extent of browsing by herbivores (Pastor et al. 1988). Nutrient supply then determines the relative abundance of conifer and deciduous forest types. Conifers are more flammable than deciduous trees, so that vegetation composition influences fire return time (Yarie 1981, Starfield and Chapin 1996). Human activities also influence forest composition through harvest management decisions and business strategies of forest industries; forest composition, in turn, affects fire probability (Starfield and Chapin 1996), nutrient cycling rates (Hobbie 1992), and regional climate (Foley et al. 1994). In summary, the major factors that determine the structure and functioning of boreal ecosystems are also strongly affected by ecosystem processes and their interactions with human activities.

Fig. 1. The regional system and its two interactive components: ecosystem and social system. The characteristics of an ecosystem (represented by a circle) are determined by several relatively independent "external state factors" (global climate, geology, time, etc.) and by interactive controls (regional climate, disturbance regime, human activities, etc.) that both affect, and are affected by, ecosystem processes. Similarly, the characteristics of a social system are affected by both external factors (international markets, state and federal regulations, history, etc.) and by interactive controls (institutions, businesses, environment, etc.). Modified from Chapin et al. (1996).



An ecosystem is also influenced by "external" factors (e.g., global climate, nitrogen deposition, international markets, and past history) that are not strongly affected by current processes in the ecosystem (Jenny 1941). Thus, ecosystems respond to global changes in these external forces as well as to local human activities and the internal dynamics of the system. However, even these "external" factors are sensitive to changes in the functioning of ecosystems, e.g., the effect of treeline advance on regional climate (Foley et al. 1994), the effect of nitrogen-fixing crops on the global nitrogen cycle (Vitousek 1994), and the effect of vegetation changes on the density of human population.

Similarly, the functioning of social systems is the net result of factors that both affect, and are affected by, the nature of their citizens, social institutions, businesses, and surrounding ecosystems (Fig. 1). For example, the nature of institutions and property rights strongly affects the sustainability of resource use by societies. Unregulated, open access inevitably leads to resource depletion and a "tragedy of the commons" (Hardin

1968), whereas private property, communal property, and state property have mechanisms that can regulate access to these resources and provide a basis for more sustainable use (Berkes 1996). The nature of these institutions depends, however, on the cultural history and pattern of use of local ecosystems. For example, the Cree Indians in James Bay, Canada, regulated their take of fish in a sustainable fashion through institutions based on communal property rights. In contrast, resource use in western society is often governed by the state through formulation of regulations (Berkes 1996). Interactions among cultures often lead to the building of new institutions, with associated effects on patterns of resource use (Berkes and Folke 1994). In western societies, where the institution of private property plays an important role, businesses mediate many of the interactions between ecosystems and social systems. Thus, within the social system there is a complex web of interactions between ecosystems, institutions, culture, and business.

Like ecosystems, social systems also respond to external factors (e.g., state and federal regulations, international markets, climate, and history) over which they have less immediate control. One dramatic change that has occurred in recent years is the emergence of transnational corporations that exert a strong influence on international markets and regulations through foreign direct investment and through international trade policy developments such as the Multilateral Agreement on Investment, NAFTA, and the World Trade Organization. Thus, many of the external constraints on the functioning of social systems have become less pronounced.

The regional system in boreal forest includes natural ecosystems, managed systems (e.g., agriculture), and social systems (Fig. 1). At the regional scale, it is impossible to separate ecological and social systems. They are tightly associated and interdependent. Major changes in either the social or the ecological system will have important consequences for both types of systems. The only way to understand and predict the future of ecological and social systems is to recognize this interdependence and to place them in a common predictive framework.

Paradoxically, however, many corporations do not recognize or incorporate the dimensions of this embedded system within their operations. Instead of perceiving a common framework, corporate decision-makers tend to view environmental systems as separate from social systems and decoupled (or loosely coupled) in terms of feedback loops. Historically, for many commercial organizations, the "environment" was considered a strictly social, political, and economic arena, with the earth as an abundant, hidden backdrop (Shrivastava 1994). Even with companies that recognize the importance of ecosystem health, an environmental ethic is rarely fundamental to business culture and decision-making frameworks. Yet for sustainable business activity to occur, individual firms, and industry as a whole, must perceive these interlinkages and manage accordingly. Sustainable industry must operate in a human, socially constructed world as well as on an ecological level (Östlund and Roome 1998).

FORCES FOR CHANGE

Any directional change in important external drivers will inevitably cause changes in social and ecological systems. Thus, recent changes in boreal climate (Chapman and Walsh 1993) and atmospheric nitrogen deposition (Vitousek 1994) have been implicated as causes of altered productivity (Kauppi et al. 1992, Myneni et al. 1997), carbon sequestration (Ciais et al. 1995), and fire frequency (Stocks 1991) in boreal forests. Similarly, changes in federal regulations about land tenure and international demand for fish, furs, and wood products have substantially altered the social systems of northern countries. Given these directional changes in external drivers, what hope is there for a sustainable future in the boreal forest?

There are two general categories of interactions that modify the response of any system to a change in input. A positive feedback amplifies the change in input, pushing the system toward a more pronounced change. A negative feedback counteracts the change in input, tending to maintain the system in its current state. The presence of negative feedbacks is a key to maintaining the long-term sustainability of social and ecological systems in their current state in the face of global changes in external drivers (Berkes and Folke 1994, Chapin et al. 1996). Factors that accelerate change (positive feedbacks) can be beneficial or detrimental, as can negative feedbacks. In the following sections, we consider the interactions of positive and negative feedbacks first in the ecological system, and then in the social system. Finally, we consider the feedbacks that integrate ecological and social components in a regional view of boreal forest sustainability.

POSITIVE AND NEGATIVE FEEDBACKS

Ecosystems

Natural ecosystems are complex networks of interacting positive and negative feedbacks (DeAngelis et al. 1986, DeAngelis and Post 1991) that operate over a range of temporal and spatial scales. Thus, both positive and negative feedbacks are important in determining the characteristics of natural ecosystems. Resource-based mutualisms of plants with mycorrhizal or N-fixing symbionts create a positive feedback that maximizes productivity, because both the host plant and the fungus or N-fixing bacterium benefit from the association. In degraded landscapes, mutualisms between plants and mycorrhizal fungi or N-fixing bacteria can enhance the resource supply and productivity of the system, demonstrating that positive feedbacks can be ecologically beneficial (Perry et al. 1989). Population growth acts as a positive feedback, because increased population size tends to cause still greater population increase. In simple two-species microcosms, population growth creates instability because one species provided with a finite food supply increases its population until the food supply is exhausted, and then the population crashes.

In sustainable ecosystems, negative feedbacks constrain positive feedbacks, such as those just described. The acquisition of water, nutrients, and light to support growth of one plant reduces availability of these resources to other plants (Tilman 1988), thereby stabilizing community productivity (Chapin and Shaver 1985). Similarly, animal populations cannot sustain exponential population growth indefinitely, because declining food supply (Malthus 1798) and predation (Hairston et al. 1960, Oksanen 1990) reduce the rate of population increase. If these negative feedbacks are weak or absent (e.g., low predation rate), population cycles can amplify and lead to extinction of one or both of the interacting species (Holling 1992). The negative feedbacks operate at the ecosystem scale, due to the finite resource supply available to support biotic activity. These ecosystem-scale feedbacks constrain the positive feedbacks that operate on single populations (e.g., the growth rate of a given species).

At the landscape scale, successional changes in forest flammability act as a negative feedback to minimize changes in annual area burned. Late successional spruce forests are more flammable than early successional deciduous forests, such as aspen. For example, fire suppression increases the fuel load in any stand and increases the proportion of late-successional flammable forests, thus increasing the probability of fire. Conversely, climatically induced increases in fire frequency augment the proportion of nonflammable, early-successional stands, thus stabilizing future fire probability. Analogously, increases in forest harvest reduce the number of remaining harvestable stands, placing an upper limit on the future rate of timber harvest in the region. If international demand for fiber increases, as expected, harvest policies must be instituted that stabilize harvest rates at times of increasing demand, if forestry is to remain a sustainable element of the regional economy. In this case, harvest policy acts as a negative feedback in the interactions between people and the forest.

Social systems

Social systems have webs of positive and negative feedbacks that are structurally similar to those of ecological systems. For example, human populations experience the same positive feedbacks associated with population growth and its constraints by food supply that occur in any population. Institutions provide an analogous source of positive feedbacks. As individuals in society amass property, they accumulate the wealth and influence to acquire progressively more property or to influence the use of property by others. Analogously, as government bodies develop regulatory power, they are confronted with an increasing list of responsibilities and expectations from society. Cultural change exhibits similar features. Rapid cultural change provides an environment in which these changes occur with increasing ease. However, there is a fundamental difference between social and ecological feedbacks. Whereas ecological feedbacks have a strong physical basis in the availability of resources to support production, social feedbacks are socially mediated, are somewhat less tangible and predictable, and can even be ignored or misconstrued. For example, corporations and corporate sympathizers can staunchly deny the existence of global warming despite strong physical evidence.

As in ecological systems, many of the negative feedbacks that constrain these positive feedbacks are based on the finite resources available to support society. The Cree Indians of James Bay, Canada provide several examples of negative feedbacks that operate in a boreal social system under conditions where commercial businesses are not well developed (Berkes 1995). First, the Cree act as an important predator on animal populations and therefore constrain the positive feedbacks associated with population growth of these populations. The decision

on where to harvest and what species to harvest is made so that harvest levels are greatest when animals are abundant. For example, beaver are harvested primarily from areas where trappers observe depletion of the beaver's food supply, but after an area is trapped for 2-4 years, it is left untrapped for 6-10 years, or until there is again evidence of overbrowsing by beaver (Berkes 1995). Similarly, switching prey between fish and caribou or changing fishing areas at times of declining catch acts as a negative feedback that prevents over-exploitation of natural populations. The respect shown for animals means that each hunter harvests only what is needed, with minimal "over-harvest" and waste. This contrasts strikingly with the positive feedback (increased fishing intensity) that often occurs in western cultures at times when fish populations begin to decline (Francis 1990). For example, supply-and-demand economics and government subsidies often maintain or increase fishing intensity in response to declining fish populations (Ludwig et al. 1993, Hilborn et al. 1995, Pauly and Christensen 1995), as in the Pacific sardine and Peruvian anchovy fisheries (Hilborn and Walters 1992), rather than decreasing predation pressure, as would be the typical population response of natural predators (Francis 1990). These policies that promote fishing in response to declining stocks act as positive feedbacks and have repeatedly caused collapse of boreal fisheries.

Although regulation and government policies are important aspects of sustainability, because they define the "rules of the game," these are external constraints imposed from the outside the corridors of business. To become truly sustainable, a shift in business culture must occur from the inside: corporate decision-makers must accept and understand the complex interactions between social and natural systems. As Courtney Pratt, past-President of Noranda Inc. (1997), suggests: "We need to make the principles of sustainable development a fundamental part of our business strategies and day-to-day operations."

Business systems

In social systems, businesses constitute an important web of feedbacks that are dominated by positive feedbacks, which currently threaten the sustainability of western boreal systems. Therefore, we consider businesses in greater detail. Business, or the market place, is a collection of loosely related systems of consumption and production that has been created by humans for humans. It is the manifestation of competing industry interests and historic consumption and production patterns. Over time, the business system has evolved away from the physical gratification of human needs toward the mental and social drive to satiate socially constructed desires. Products and services are no longer produced and consumed primarily for their intrinsic properties (use values), but rather for their symbolic properties (Venkatesh et al. 1993). The business system actively constructs the symbolic aspect of the marketplace through advertising and marketing campaigns. Thus, the consumption of previously tangible goods and services often becomes an abstract social activity: in essence, the consumption of signs (Jhally 1987, Baudrillard 1988). Many of these desires are not satiable without ongoing consumption, leading to a positive feedback in which consumption creates an ongoing need for more consumption.

Consumerism, i.e., the business system, is the manifestation of a complex set of social processes (Venkatesh et al. 1993) and the drive for mass production (Fullerton 1988). It is a component of the social system that has been strategically created by corporations through use of sophisticated marketing and communication technologies. As early as 1914, a U.S. advertising executive, Harry Tripper, explained that mass production required that people must "be taught to use more than they formerly had used" (Fullerton 1988). Planned obsolescence added a tangible need for ongoing consumption, because things fell apart, and people bought more. In time, we have come to accept this market characteristic as a social norm. As consumerism has progressed, businesses have concentrated their efforts on generating consumers and a symbolic marketplace, through which they actively attempt to gain competitive advantage. People tend to become socially consuming actors in an environment of consumerism and brand loyalty.

The whole philosophy of consumerism is built on the need to generate and amplify positive feedbacks. It is a "throughput system" in which costs to the producer are reduced through economies of scale. Costs unrelated to production (e.g., ecological impacts) are externalized from the system, which tends to remain closed to nonconsumer feedbacks. This philosophy developed at the beginning of the industrial revolution through expanding use of natural capital (Berkes and Folke 1994). As long as the costs of renewing these resources were not borne by the producer or consumer, there were strong economic incentives to enhance consumerism. Corporations collectively create local and international markets and strategically develop loyal consumer followers. Corporations are committed to growth and seek to intensify positive feedbacks associated with growth whenever possible. The corporate monitoring systems tends to emphasize the need to collect information on social feedback (such as market share) and to a lesser extent, on ecological feedback.

Under a system of competitive advantage, the more competitive moves that a company initiates, the better

its performance (Chen 1996). Searching continuously for new sources of advantage is a key motivating force for corporate activity, which tends to intensify positive feedbacks in the business system (Porter 1980, 1985). Corporate actors are constantly monitoring these feedback loops through data provided by market share and competitive intelligence reports, and they adjust their actions to further magnify the positive feedbacks.

Under a hypercompetitive market environment, the business system is so dynamic that firms can only achieve temporary, *unsustained* competitive advantage (D'Aveni 1994). In this situation, corporations deliberately introduce market variability and destroy their own sources of competitive advantage in order to achieve temporary, unsustainable competitive advantage. Here, positive feedback loops are used unpredictably to gain temporary advantage, resulting in highly unstable and unpredictable markets. These competitive advantages shift rapidly so that issues such as forest sustainability, which must be calculated over decades to centuries, are not a strong consideration.

Over the long term, it is conceivable that the positive feedback loops of perpetually increasing consumption may overwhelm negative social and ecological feedbacks and lead to the collapse of the regional system in its current form, for example, the depletion of harvestable forests and the social system that these forests support. Total system collapse could occur if negative social feedbacks within the business system do not occur both at an individual firm level and at the macro level of the marketplace. Because ecological feedbacks are socially mediated within the business system, points of ecosystem instability are not clearly transferred from the ecological system through the social system and into the business subsystem.

Despite the purported logic of economic efficiency, theorists have argued that corporations and other organizations are actually constellations of power and influence (Perrow 1986, Pfeffer 1992). Rational efficiency is often an effective rhetoric that obscures the unregulated power of the few over the many (Perrow 1986). For example, there is often significant overlap of board members among companies within specific industries, resulting in a clear consolidation of power and small-group decision-making. Although competitive advantage remains a compelling force in business activity, power relations constrain such "free market" rhetoric. Economics becomes a way of "keeping count" while the ultimate goal may be "winning the game" on both an industry and individual basis.

Just as in ecosystems, there must be negative feedbacks that constrain the positive feedbacks associated with businesses. Perhaps the most important of these is the finite economic resources that support the consumer system. Although the success of an individual business is governed by positive feedbacks (just as with the population growth of a plant or animal species in an ecosystem), the limited economic resources of the social system and the finite biological resources of ecosystems mean that the positive growth of some businesses is inevitably associated with the decline and disappearance of others, so that the total output of private enterprise is constrained. However, these competitive interactions among businesses provide only a weak negative feedback to the total magnitude of resource use.

In addition, nongovernmental organizations (NGOs), consumers, and government regulatory agencies can generate negative feedback loops within the business system. Consumers can choose to purchase "green products" or demand ecologically responsible corporate behavior. For example, the continued consumer and NGO pressure on Macmillan Bloedel to stop harvest of old-growth forests generated a strong negative loop (a consumer boycott) that eventually resulted in Macmillan Bloedel announcing an end to such practices (Boulton and Alden 1998).

Lands for Life: a boreal forest example

During 1997-1998, the Ontario government initiated a review of Ontario public lands, encompassing 46 x 10^6 ha of central and northern Ontario (58% of Ontario's forest). The Lands for Life land-use planning process will make recommendations on land classification and assign areas for business use (forestry, mining, and tourism) and potentially will designate portions of the forest as protected areas. Three regional roundtables were established to generate public consultations on land-use decisions.

From the business perspective, the boreal forest in Ontario is a necessary and valuable input to the business system. Despite ecological concerns about the need for protected areas within the boreal system, forestry companies and the Ontario Forestry Association actively campaign for the Ministry of Natural Resources in Ontario to open the entire boreal system to business activity, including areas that are currently protected as parkland. The business system, which consists of forestry, mining, and tourism companies and associations, actively lobbies the roundtables for a "multiple use" land categorization. Although it is open to public consultation, the membership

of the roundtables has been criticized by environmental groups for an unduly high percentage (51%) of representation from business and industry.

The forestry companies openly acknowledge that their desire for boreal resources stems from the business need to fulfill ongoing consumption (positive feedback) from the social system. For example, Buchanan Forest Products informed the Boreal West round table that "every hectare of forested land in the northwest region, and every tree on this land is needed to run our sawmills" (Canadian Parks and Wilderness Society 1998) Like many business systems, the forestry companies downplay the importance of negative feedbacks from the ecological system and actively attempt to nullify the negative social feedback of environmental NGOs (e.g., the Wildlands League and World Wildlife Fund) within the Lands for Life planning initiative. Mining and forestry industries aggressively promote a message of economic risk as a result of scarcity: a threatened negative feedback to the business system if perpetual access to boreal resources is not assured.

A governmental decision to grant perpetual tenure over resource use to industry would be an example of short-term social feedbacks, operating within the business system over months to years, that are disconnected from longer term (decades to centuries) ecosystem feedbacks. Any ecological feedback that enters into the business system must be socially mediated; those feedbacks that do not succeed in becoming symbolic messages can be effectively ignored by forestry companies, government agencies, and the boreal roundtables. Unless negative feedback loops emerge from within the business system (such as from consumer boycotts, NGO pressure, or regulatory action), forestry decisions on Ontario's boreal system may not adequately address the importance of ecological feedback loops. As with Canadian Atlantic fisheries, this realization may come after the point of instability has been reached or exceeded.

General implications

In general, businesses are not immune to the importance of sustainability. Some businesses seek to develop products with minimal environmental impact. In part, this information is used to strengthen competitive advantage by espousing "green alternatives" that are intended to increase consumer loyalty. Nonetheless, the recognition by business of sustainability as one factor that governs consumer choice provides an opportunity to develop a negative feedback to consumerism within the normal "rules of the game." This possibility has not been thoroughly developed.

The more typical approach to developing negative feedbacks within the social system is through government regulations, trade policies, taxes, and boycotts that constrain consumerism. However, these policies are strongly influenced by business lobbies and consumers, by social and cultural institutions, and by special interest groups such as environmental activists and consumer lobbyists, making these constraints highly variable and difficult to predict. More importantly, when consumption of one product is constrained by regulations, corporations look to develop alternative markets to increase their sales and overall consumption. The difficulty is that business and social systems tend to separate business decisions from other social and environmental issues. How do we integrate the business and environmental issues into a common process?

DESIGN CRITERIA FOR A SUSTAINABLE BOREAL SYSTEM

It seems obvious that the current rate of economic growth stimulated by the business system cannot continue indefinitely. However, it is unlikely that western society will return to conditions that preceded the Industrial Revolution. How can we achieve a modestly prosperous middle ground in which the limitations of the natural environment provide effective constraints to the business system (Berkes and Folke 1994)? An overarching premise is the recognition that industry sustainability must operate in a human, socially constructed world, as well as on an ecological level (Östlund and Roome 1998). Furthermore, the translation of ecological feedbacks into socially embedded feedback loops is a critical method of reconnecting these "separate" systems.

The first step in this reconnection is to convince corporate and consumer actors of the importance of sustainability as a fundamental precept: that the harvest of renewable resources cannot exceed the productive potential of the land. If the social system does not restrict harvest to a level consistent with current productivity, ecological processes inevitably come into play, reducing productivity to a level that can no longer support the current social system. The undermining of the social system through over-exploitation of the natural system

has occurred repeatedly, e.g., conversion of the "fertile crescent" into desert, the "dust bowl," the deforestation of southern reaches of the boreal forest in Minnesota, etc. Despite clear evidence for the physical and biological nature of these feedbacks, they can become ambiguous and seem unimportant when they enter the realm of the business and political systems. For example, sawmills are typically amortized over 15 years, considerably shorter than the 50-100 yr rotation times of the forest stands on which they depend. Businesses therefore do not need to consider long-term sustainability in deciding whether a new sawmill will be profitable. An important educational goal is to make this discrepancy in the time scale of feedbacks obvious to all members of the social system, so that the supply of timber and total costs of supplying it can be averaged over the rotation length of a stand.

In order to accomplish this shift in perspective, we must (as agents of change) understand the culture of corporate decision-making on the basis of the individual firm and the collective industry. Because corporations act out of both power and economic motivations, it is critical to understand how decisions are made and how ecological feedbacks are socially translated into the business system. Understanding how, and on what basis, consumer decisions are enacted opens an additional indirect means of influencing corporate decision-making.

Although education may be a critical step in changing corporate culture, it is not the only approach. In general, people (corporate actors and consumers included), do not always make decisions based on information (Andreason 1995). Attitudes, feelings, and a strong belief in behavioral control each contribute to behavioral change. Pressure from outside social groups also influences corporate (and consumer) behavior (Andreasen 1995). By understanding how individual corporations make decisions and implement activities, we can then develop social programs that are effectively targeted toward changing this behavior and moving corporate culture toward sustainability. If the existing constellations of corporate power are understood, it is possible to influence key business decision-makers on cultural and economic bases, and to change existing power relations and infuse these constellations with more sustainable cultural ethics.

Once the importance of sustainability is recognized, corporations must expand their information-monitoring systems to actively collect a broad range of ecological feedbacks in addition to social feedback. Furthermore, the costs of sustainability must be integrated into business decision-making, reporting, and financing, rather than being borne by the residents of a region. International codes of sustainable conduct can provide formal organizational legitimacy for undertaking sustainable accounting and reporting. Yet, these codes must clearly specify effective means of verifying performance, including independent monitoring on a local and global basis (Culpeper and Whiteman 1998). Environmental costing and reporting is a related mechanism of corporate accountability. Reporting based on sustainable development goals provides a more balanced picture of corporate activity and long-term system viability.

Although they are important, verification and reporting occur after the fact; that is, these tools provide information on the ecological impact of corporate behavior. However, it is also critical for a sustainable industry or firm to integrate environmental ethics into its daily operations. The broad inclusion of environmental assessments within corporate decision-making frameworks needs to occur. The increased prevalence of multi-stakeholder environmental negotiations (Gray and Wood 1991) can help to ensure that ecological feedbacks are incorporated into the business system. Integration of social and natural systems must occur on an integral, ongoing basis if sustainability is to take root (Culpeper and Whiteman 1998). In addition, local community involvement or models of community property management need to be explored alongside more traditional corporate governance frameworks (King 1995). Government regulations, a form of negative social feedback loop on the business system, must reinforce the need for integrating ecological feedbacks into the business system. Ecological impacts should not arise only in "special" cases, when regulations requires environmental consideration.

Finally, international trade and investment agreements must integrate boreal forest costs and benefits over the duration of natural disturbance cycles, so that short-term benefits of profits to businesses and wages to local economies are balanced against the opportunity costs of alternative development strategies. Specifically:

1) Sustainable yield must be more realistically assessed in light of processes such as soil erosion vs. weathering rates, increased nitrogen and sulfate deposition, projected climatic changes, probability of insect outbreaks, and fire, etc. In the past, the forest industry has been overly optimistic about future yields.

2) The costs of resource use must become associated with the sale of forest products. For example, management agencies should no longer subsidize timber harvest at public expense, through road construction. Costs such as lost recreation potential and degraded fisheries should be included, as should the costs associated

with maintaining forests for production (e.g., fire control). Only when the costs are associated with the product can market forces become an effective constraint on resource use. Once costs are adequately assessed and assigned, there is a market mechanism to convert a system that emphasizes throughput (i.e., maximum production) into one that emphasizes efficiency (Berkes and Folke 1994).

3) Owners of forest land should accrue the benefits that growing forests provide (fisheries, tourism, carbon sequestration). If carbon taxes are assessed in proportion to net carbon emission of each country, there will suddenly be a large economic benefit to growing forests, if these forests are converted into products that decompose more slowly than they would in the forest. Many of these products with a long "life" include high-value products such as finish lumber, rather than paper. These high-value products can often be produced where the trees are harvested, so that the economic benefits of forest harvest occur in the same place as the costs. This was obviously key to the success of the Cree fishing and hunting management of resources. Regional decision-making will be successful only if the costs (such as lost tourism) are integrated over the rotation time of the stand.

4) Costs of the business system should be more tightly tied their production and consumption. For example, in Basel, Switzerland, each citizen is charged the real cost of collecting trash. A small bag of trash costs each person two dollars. Establishment of this policy immediately increased the proportion of materials that were recycled and improved the economics of recycling. Consumers quickly shifted preference to products with the least amount of packaging, leading to a reduction in the amount of packaging used in many products.

5) The system must be flexible in the face of perturbations such as forest fires, economic downswings, and changing demand for wood products.

The sustainability of the boreal forest cannot be divorced from the future of people who occupy the boreal zone. People will continue to impact boreal ecosystems, and the ecological processes in boreal forests will continue to determine the resources and ecosystem services required by its residents. To understand the future state of the boreal zone, we must understand the ecological, social, economic, and business interactions that link ecological and social systems into a common regional system, and the feedbacks that govern changes in these interactions. There are currently many positive feedbacks, associated with changes in global climate and the global economic system, that threaten to amplify changes that are occurring in the boreal zone. The sustainability of boreal forest requires close collaboration among natural and social scientists to identify and implement negative feedbacks that will reduce the impact of these forces for change. These negative feedbacks include ecologically based limits to harvest, incorporation of the costs of environmental degradation into the costs of timber harvest, development of forest products whose economic benefit resides at the regional level, and consideration of the social and ecological impacts of inevitable fluctuations and changes in the boreal system.

RESPONSES TO THIS ARTICLE

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Address of Correspondent:
F. Stuart Chapin
Institute of Arctic Biology
University of Alaska
Fairbanks, AK 99775
Phone: 907-474-7922
Fax: 907-474-6967
fschapin@lter.uaf.edu
