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Sustainability Issues for Resource Managers

Technical Coordinators

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Abstract

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Throughout their history, conservation science and sustainable-yield management have failed to maintain the productivity of living resources. Repeated overexploitation of economic species, loss of biological diversity, and degradation of regional environments now call into question the economic ideas and values that have formed the foundation of scientific management of natural resources. In particular, management efforts intended to maximize production and ensure efficient use of economic "resources" have consistently degraded the larger support systems upon which these and all other species ultimately depend. This series of essays examines the underlying historical, cultural, and philosophical issues that undermine sustainability and proposes alternative approaches to conservation. These approaches emphasize the relations among populations rather than among individuals; the integrity of whole ecosystems across longer time frames; the importance of qualitative as well as quantitative indicators of human welfare and sustainability; and the unpredictable and interdependent interactions among "natural," scientific, and regulatory processes.

Keywords: Environmental ethics, environmental history, fisheries management, resource conservation, resource economics, sustainability.

Foreword

The European presence in North America brought to the fore new systems of reckoning with the natural world on the continent; structures of language that embraced objectivist, instrumentalist, and reductionist views of the material realm; and the introduction of ideas new to the Americas about the exclusive ownership of land and water. With the emergence of the United States as the dominant political and economic presence on the continent—and especially during the period of the explosive growth of industrial capitalism following the Civil War—the conquest, mastery, and development of the natural environment became the driving force in American development. The stories associated with Euro-American expansion, especially into the western reaches of the continent, are deeply embedded in the national mythology; collectively they suggest an almost transcendental belief in the efficacy of the unlimited manipulation of the natural world, whose larger purpose and function was the benefit of humankind.

By the early years of the twentieth century, the conceptual framework for that pragmatic, instrumentalist, and commercial view of nature embraced Progressive conservationism, the assumption that orderly, systematic, and engineering approaches toward the natural world would bring greater material benefits to an ever-increasing number of people As such, conservation ideology preached virtues that were consistent with the modernizing world of industrial capitalism: efficiency, the elimination of waste, and the development and scientific management of resources. During those heady years when the lumbering, fishing, and mining industries boomed across the American West, politicians, newspaper editorialists, and a host of publicists extolled the material advantages to be gleaned in the great outback. To build stable and progressive communities and to work toward a sustainable future, boosters argued, the region required only capital, the technical ability, and a continued influx of enterprising people to transform nature's bounty to the benefit of its citizens.

As the long twentieth century draws to a close, however, those once popular stories about earthly dreams being realized in the fabled land of promise seem distant and far removed from our contemporary world of vanishing species and diminishing resources. For the first time since the inception of the United States in the late eighteenth century, a sizable public audience is beginning to question and rethink the deeper meaning of the idea of progress. Today, those who have been the more reflective about environmental changes tend toward the darker view of matters. William Howarth articulated that mood in a 1987 review essay about the American West. "The old landscape of hope has faded," he remarked. "Today the western news is of dying farms and toxic dumps, the latest detonation at Ground Zero." The sense of crisis that increasingly infuses the stories we tell about the natural world is centered in a questioning about larger issues: the idea of "progress"; a market- and science-driven propensity to examine isolated segments rather than greater ecological wholes; fuzzy ideas about the nature of science and its relationship to the management of resources; and an inability to fully grasp the complexities of the human condition and its acquisitive tendencies. As Arthur McEvoy, one of the contributors to this collection, observes:

[1]Howarth, William. 1987. America's dream of the wide open spaces, *Book World,* p 4

> All of the dualisms that underlie our traditional thinking about the world, between culture and nature and law and markets and so on, are so deeply embedded in our culture and our legal system that it is sometimes hard to tell when they are at work in our thinking.

Western science and its accompanying thought world—centered firmly in the material realm of production, consumption, and the endless appropriation of nature—are at the root of our contemporary dilemma and the problems we are having with our places of habitation.

The underlying historical, cultural, and philosophical issues brought to bear on the management of natural resources in the United States are the centerpiece of the papers presented here. These arguments are, in different ways and with varying degrees of complexity, critical of traditional forms of economic development. The collective result of those human activities, according to Courtland Smith, is a full-scale "assault on the environment as we know it." Conventional strategies of economic growth and progress, these contributors make clear, have not led us to the promised land. Instead of achieving a material world of sustainable comfort, what we have is a morass of continuing environmental crises that are mostly the consequence of our cultural behavior. The writer William Kittredge, who has witnessed the great engineering transformations that have taken place across the western American landscape, remarked with bitter irony about his family's agricultural enterprise on the desert sage lands of southeastern Oregon: "We shaped our piece of the West according to the model provided by our mythology, and instead of a great good place such order has given us enormous power over nature, and a blank perfection of fields."[2]

Policy makers in the United States—resource managers, politicians, administrators, scientists, and their larger public audiences—have never been charged with "Thinking Like a Mountain," Aldo Leopold's famous pronouncement about the connectedness of human and natural systems. Instead, the western world and the United States in particular have pursued market imperatives, predicated on maximizing the productions of nature. Over the years, federal agencies and private organizations have sought to protect the erosion of that "natural wealth" through a variety of engineering adjustment mechanisms to sustain acceptable levels of those resources. The scientists, politicians, vested interests, and bureaucrats who supported those positions must now reckon with a new reality—that their fondest hopes and dreams have largely turned to disaster.

The engineering and production-driven imperatives that were the guiding force behind resource-management decisions have been based on a belief that landscapes could be made perfectible; that scientific and technical expertise could be employed to improve the material and social condition of humankind; and that the natural world could be endlessly manipulated to achieve that end. *Time* magazine epitomized that attitude in a 1951 article that praised the control and management of forest lands and waterways in the Pacific Northwest for creating a new frontier "made ready for man by spectacular engineering." *Time* cited the scientific work of the Forest Service and the engineering genius of the Bureau of Reclamation and the Army Corps of Engineers, whose combined achievements meant that the United States could "expand almost indefinitely within its present boundaries." The magazine gave its full endorsement to federal agencies who were "making rivers behave," whose dams were accomplishing their ends through "geographical judo."[3]

We have some sense now that those words reflect the pathologies of an arrogant cultural view of nature, of a pretend scientific expertise gone wrong, of a reductionist attitude toward the natural world. In an opinion column in the Portland *Oregonian* early in 1995, a commercial fisherman pointed out that salmon had always played an important cultural and economic role in the life of Northwestemers. "Can anyone . . . imagine Oregon without salmon," the writer asked?[4] For anyone familiar with the growing biodiversity crisis in the region, there is nothing surprising in the fisherman's query.

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[2] Kittredge, William, *Owning it all St.* Paul, MN: Graywolf Press. 1987, p. 62.

[3] *Time,* July 30, 1951, p. 48-51.

[4] Portland *Oregonian,* February *7,*1995.

Contents

Introduction

Daniel L. Bottom

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> All [of the colonists of the 'new' lands] have arrived at what they are convinced is a virgin land. All have found resources that have never before been tapped and all have experienced a short period of tremendous boom, when people were bigger and better than before, and when resources seemed so limitless that there was no need to fight for them. Because there was enough for everyone, egalitarian, carefree societies with the leisure to achieve great things have prospered. There was a period of optimism, when people imagined great futures for their nations. Inevitably however, each group has found that the resource base is not limitless. Each has experienced a period when the competition for shrinking resources becomes sharper. The struggle between people increases, whether it be a class struggle or a struggle between tribes. If people survive long enough, they eventually come into equilibrium with their newly impoverished land—and their lifestyles are ultimately dictated by the number of renewable resources that their ancestors have left them.
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> —Flannery 1994, p. 344

The Pacific Northwest—at the edge of America's continental frontier and at the close of the second millennium—is entering the latter stages in the history of colonization of all "new" lands as described by Flannery. Here, the entire sequence has unfolded in the course of a few generations of European colonists: the rapid economic expansion, the unbridled enthusiasm of America's manifest destiny, the increased competition for dwindling resources, the social upheaval of resource collapse. Today, amid declining fisheries, forests, and watersheds, North westerners are struggling to achieve equilibrium with their no longer new land and to decide the quantity and quality of resources they will leave their children.

Perhaps what is unique about the history of European settlement in this region is that it coincided with America's industrial revolution. The shape of today's Northwest landscape is not the inadvertent outcome of a long history of unconscious decisions. It is, by and large, the product of much deliberate planning and technological design. Moreover, unlike the 250 years of landscape change that led to the decline of native species and ecosystems in nineteenth-century New England (Cronon 1983, Merchant 1989), the stunning collapse of Northwestern fisheries and forests during this century occurred in the presence of a complex regulatory and management system established, in part, to prevent it. This system was founded on the principles of scientific management, which provided information and technologies to control production, minimize waste, and ensure the equitable distribution of economic resources for all people. Despite decades of planning and modeling for sustainable resource use, management results in the Pacific Northwest nonetheless support the general claim that "there is remarkable consistency in the history of resource exploitation: resources are inevitably overexploited, often to the point of collapse or extinction" (Ludwig et al. 1993). Today, an unprecedented number of natural-resource professionals employed by state and federal governments, universities, and private industries are witnessing and documenting biotic impoverishment first hand. More than just another example in the history of natural resource decline, the Pacific Northwest has become a case study in the failure of the traditional tenets of scientific management.

Not surprisingly, the inability to sustain so-called renewable resources has sparked much debate and introspection among the various professions that were supposed to ensure resource renewal.

Several years ago, the Oregon Chapter of the American Fisheries Society began a series of interdisciplinary symposia to discuss the underlying cultural and philosophical issues in the region's expanding conservation crisis. The first symposium, held in 1989, dealt with ethical issues in conservation and the moral responsibilities of resource managers toward ecosystems, the public, and future generations (Reeves et al. 1992). A second series of papers contained in this volume is from the 1990 Oregon Chapter meeting. This collection examines the cultural and historical roots of resource depletion and the implications for developing more sustainable relations between nature and culture. Although much has changed since 1990, these papers are no less relevant today than when they were first presented. To understand why, we need only consider the events of recent years.

At the time of the 1990 Oregon Chapter meeting, global and regional environmental concerns were receiving increasing media attention. What has become common knowledge seemed extraordinary then: an expanding hole in the Earth's protective ozone shield, the warming of the Earth's climate through carbon dioxide enrichment, the unprecedented rate of global species extinction. In the Northwest, a storm was brewing over how to manage late-successional forests after a federal recommendation to list the northern spotted owl as a threatened species. Wildlife biologists became embroiled in controversy as they developed conservation strategies to ensure the viability of old-growth-dependent owls. At the same time, aquatic biologists were becoming increasingly concerned about the fragmentation of interconnected stream systems and the cumulative threat to many native fish species. At its annual meeting, the Oregon Chapter passed a resolution ("Biological Diversity and Global Environmental Change") calling on state agencies and fisheries professionals to take steps to minimize the risks of global and regional change to native aquatic species and ecosystems. Then, in a final footnote on the last day of the meeting, biologist Willa Nehlsen, without fanfare, described the widespread decline of Pacific salmon stocks. No one fully anticipated the impact of these findings.

One year later, Nehlsen, Jack Williams, and Jim Lichatowich published their paper, "Pacific Salmon at the Crossroads," a catalog of endangerment that listed 214 stocks of Pacific salmon and steelhead at risk of extinction or of special concern in Washington, Oregon, Idaho, and California (Nehlsen et al. 1991). By this time, the Idaho and Oregon chapters of the American Fisheries Society had already joined several environmental organizations in calling for a status review of Snake River sockeye and Chinook salmon stocks under the federal Endangered Species Act (ESA). But the "Crossroads" paper made it clear that the problem was more than just a few upper river stocks affected by the gauntlet of mainstem dams on the Columbia River. Scores of other populations throughout the Columbia basin and in the smaller coastal rivers of all the Pacific states were also in trouble. Soon a rash of petitions were filed for listing other salmonids as threatened or endangered. A dramatic illustration of the magnitude of the problem was the steady decline of coho salmon, once the mainstay of the Oregon troll fishery and, today, a candidate for listing under the ESA.

Within a few years, the regional decline of wide-ranging anadromous salmon—a cultural symbol of the great Pacific Northwest—had shifted the political debate from spotted owls in old-growth forests to the restoration of whole ecosystems and their associated human economies. These ideas received a national hearing in 1993 when President Clinton convened a televised forest conference in Portland, Oregon. This meeting was followed by the report of the Forest Ecosystem Management Assessment Team (FEMAT 1993), whose analyses and recommendations covered numerous at-risk fish species and stocks and more than 1,000 plant and animal species thought to be associated with late-successional forests. Such concerns were not confined to the coastal rainforest region in the range of the northern spotted owl; even before the FEMAT report was completed, others also began to assess ecological conditions east of the Cascade Range. An Eastside Forests Scientific Society Panel (Henjum et al. 1994) concluded that watersheds and landscapes of eastern Oregon and Washington are highly degraded. The panel's final report called for developing a "coordinated strategy for restoring the eastside landscape and its component ecosystems."

The papers in this volume are not a description of the resource crisis in the Pacific Northwest. But they were solicited to better understand its common roots. As a result, this collection of papers provides a benchmark of changing ideas in the midst of what one day may be considered a revolution in resource conservation. Certainly the principles of "ecosystem management" now emerging from the Northwest experience are well represented in Bryan Norton's melding of hierarchy theory in ecology with Aldo Leopold's metaphor, "Thinking Like a Mountain." So is Courtland Smith's critique of the traditional indicators of economic success implicit in many new efforts to establish ecological performance measures in resource conservation. Surely Regier and Baskerville's history of New Brunswick forests and North America's Great Lakes offers guidance for a regional economy that has not yet made the difficult transition to "sustainable redevelopment." And clearly Arthur McEvoy's description of the "tripartite interaction between ecology, production, and management" in California's fisheries underscores why many policy makers and scientists now propose "adaptive management" as an alternative approach for conserving unpredictable natural-cultural systems.

But despite their general agreement that traditional sustainable-yield management has failed and that individual resource decisions must be placed in a broader spatial and temporal context, these papers also reveal a fundamental tension between the moral issues of sustainability and the rational prescriptions intended to achieve it. If the failure of people to protect other species is a reflection of their moral disinterest, might not all conservation plans and economic prescriptions—the products of an intellectual detachment—prove self-defeating? How can we prescribe a moral concern for biological diversity or plan our way to healthy ecosystems? Becoming committed to wildness in all its unpredictable and messy complexity requires more than just a cognitive transformation. I think David Ehrenfeld (1989) had it right when he said, "The ultimate success of all conservation will depend on a revision of the way we use the world in our everyday living when we are not thinking about conservation." Perhaps what we colonists of the "new" lands do and do not value must undergo the same test of survival as do all species (including our own) whose existence is supported or jeopardized by these values. Perhaps through the unconscious process of co-evolution between nature and culture, people will begin making the kind of conscious choices that will allow them to "eventually come into equilibrium with their newly impoverished land."

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Sustainability Across Generations: Economics or Ethics

Bryan G. Norton

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Aldo Leopold began his career as a forester in the arid Southwest Territories, and ended it as a college professor and public-spirited, if much-maligned, Conservation Commissioner in Wisconsin. It may seem a bit odd to begin a discussion of fisheries management by citing Leopold—whose preferred management medium was sand, not water, and whose ethic was of the land, not the sea—but Leopold's experiences are relevant because he was self-conscious and philosophical about both his successes and his failures, and he proposed some general theories and conclusions about management over long periods of time. Some of Leopold's general conclusions about environmental management, I am convinced, are very relevant to managers of fisheries today.

Early in his career, Leopold set out, among his many other tasks, to eradicate wolves in the Southwest Territories. By the mid-1930s, he had switched from a conscientious and efficient predator eradicator to a predator protector (at least in remote areas). By this time, Leopold was also committed to polishing old writings and creating some new material for a collection of nature essays. Leopold seems to have led two parallel lives: one as a hard-headed resource manager, trying to make resources available to people; the other as a romantic, sprinkling his nature essays with empathic metaphors and speculating about our obligations to protect the natural world. The collection of essays, eventually to be called *A Sand County Almanac* (1949), was accepted for publication by Oxford University Press just a week before Leopold's death; the book represented the highest flowering of Leopold-the-romantic.[1]

The collection was to be illustrated by Albert Hochbaum, Leopold's former student and Director of the Delta Duck Station in Delta, Manitoba. Although Hochbaum was unable to complete the illustrations, he remained a sympathetic but firm critic of Leopold's efforts in the last decade of the older man's life. In 1944, Hochbaum, in criticism of the essays he'd seen so far, wrote: "I just read they killed the last lobo in Montana last year. I think you'll have to admit you've got at least a drop of its blood on your hands." He proceeded to insist that Leopold acknowledge that he, too, had once been a despoiler (Meine 1988, p. 453).

Hochbaum, therefore, forced Leopold to address the conflict between the romantic message of his essays and his own actions as a young game manager. Leopold-the-manager had already reversed his position, arguing in a scientific vernacular for predator protection in remote areas:

> It is probably no accident that the near-extinction of the timber wolf and cougar was followed, in most of the big-game states, by a plague of excess deer and elk and the threatened extirpation of their winter browse foods.... It is all very well, in theory, to say that guns will regulate the deer, but no state has ever succeeded in regulating its deer herd satisfactorily by guns alone. Open seasons are a crude instrument and usually kill either too many deer or too few. The wolf

[1] My account of Leopold's experiences owes much to Meine (1988) and Flader (1974).

> is by comparison, a precision instrument; he regulates not only the number, but the distribution, of deer. In thickly settled counties we cannot have wolves, but in parts of the north [of Wisconsin] we can and should.
>
> —Meine 1988, p. 458

Leopold's argument is symptomatic of his evolution as a resource manager. Leopold attended the Yale Forest School, which was founded with a gift from Gifford Pinchot's family, and immediately entered Pinchot's Forest Service in 1909. Leopold generally followed Pinchot's utilitarian approach, which emphasized use of resources, especially for material production (Hays 1959). Pinchot said, for example:

> the first great fact about conservation is that it stands for development.... (Its} first principle is the use of the natural resources now existing on this continent for the benefit of the people who live here now.
>
> —Pinchot 1947, p. 261

Pinchot relied on economic calculations to determine policy, and limited production only when threats of shortages and degradation of productive systems became obvious. It was in Pinchot's spirit that Leopold had organized sportsmen and stockmen to eradicate wolves and mountain lions from the Southwest Territories. In a 1920 speech before the Sixth American Game Conference, Leopold had said:

> It is going to take patience and money to catch the last wolf or lion in New Mexico. But the last one must be caught before the job can be called fully successful.... [W]hen they are cleaned out, the productiveness of our proposed refuges and plans for regulation of kill, will be very greatly increased.
>
> —Meine 1988, p.181

But in 1943, goaded by Hochbaum, Leopold composed a brief, but powerful, *mea culpa* on wolf eradication. Leopold chose a metaphor, "Thinking Like a Mountain," to express his own journey from wolf eradicator to wolf protector and land ethicist. Leopold told a story, perhaps fictional, of an incident that occurred on a "reconnaissance mission" in the Forest Service's vast holdings in the Southwest Territories.

He tells of how he and his fellow crew members shot a she-wolf from a high rim rock; Leopold approached the mortally wounded wolf in time to see "a fierce green fire dying in her eyes." "I was young then, and full of the trigger-itch," he confessed. "I thought that because fewer wolves meant more deer, that no wolves would mean hunters' paradise." Leopold perceived the result: the bones of the desired deer herd, "dead of its own too-much," littered the mountain.

The theme of the essay is time: "Only the mountain has lived long enough to listen objectively to the howl of the wolf," he said. Thinking like a mountain is putting oneself in the frame of time of the mountain, and "a mountain lives in mortal fear of its deer." For good cause: "while a buck pulled down by wolves can be replaced in two or three years, a range pulled down by too many deer may fail of replacement in as many decades." Leopold was here recognizing how and why his early deer management plan had gone astray: utilitarian, economically calculating management was management conducted from the time perspective of humans. Consumed with human cares, we strive for "peace in our time," and find it hard to see things from the mountain's viewpoint, a viewpoint measured in ecological and geological time, not human time (Leopold 1949, p. 129-133).

To help the reader understand the differing frames of time, Leopold-the-romantic created a metaphor. The mountain was personified: the dead sage became bones moldering, along with the deer bones, under the high-lined junipers. The mountain has not only a vegetative skeleton; it also thinks, and feels fear. If we are to manage nature without raising havoc, we must think like the mountain thinks. The metaphor of the living mountain drove Leopold's re-thinking process; organicism aided him in thinking as the mountain thinks, in the longer durations of ecological time.

The pattern of Leopold's thinking on wolf management was reinforced by his more detached observation of the Dust Bowl phenomenon. Leopold was careful to point out that he was not an agronomist, that his observations were only those of a nonprofessional. But he had traced what he called "illness" in natural communities, especially in the Southwest Territories, even before venturing a general theory of fragility of arid systems in 1923, and was hence moving toward an explanation of the Dust Bowl well before it occurred (Leopold [1924] 1979). His explanation of the Dust Bowl, by then a fait accompli, was summarized in a succinct, but powerful passage near the end of "Thinking Like a Mountain." Just after summarizing the lesson he'd learned about mountains fearing deer, Leopold made the comparison:

> So also with cows. The cowman who cleans his range of wolves does not realize that he is taking over the wolf's job of trimming the herd to fit the range. He has not learned to think like a mountain. Hence we have dustbowls, and rivers washing the future into a sea.
>
> —Leopold 1949, p. 132

Leopold employed ecological terms to discuss these two cases—deer irruptions and the Dust Bowl—and he thereby developed a paradigm of environmental management gone awry. Leopold was ready, however tentatively, to articulate his criticisms of Pinchot-style management and propose a broad "theory" of environmental management of his own. The new theory represented an application of Charles Elton's community model of ecological systems. Leopold met Elton in 1931 at a conference on natural cycles, and they became immediate friends. Already acquainted with Elton's important 1927 book, *Animal Ecology,* Leopold began in the 1930s to apply ecological theory to management problems (Meine 1988, p. 282-284). According to Elton's theory, species are understood functionally, in terms of their contribution to a larger, biotic community.

Applying Elton's concepts, Leopold theorized as follows: The failures in the two case studies resulted from attempts to increase the output of a resource base through more intensive management. In both cases, initial successes were registered because productivity increased dramatically. And in both cases, after a few years or decades, productivity crashed. Elton's theory provided an explanation of the salient facts: ecosystems embody redundancy, with many species fulfilling each function. The system changes dynamically through time; its complexity and redundant energy pathways sustain the system through these changes.

Elton's ecological model explained the breakdown encountered in managed systems: complexity, which emerged over millennia of evolution and competition, is disrupted as pervasive human activities destroy redundant pathways in the functions of the community, the flows of energy through the biotic pyramid have been simplified and reduced. The system is ill.[2] Only sharp observers can see the gradual development of the illness. But then, usually in response to environmental stress—a hard winter or a prolonged drought—the system collapses into serious illness. The theory therefore explained large-scale failures of environmental management—the Dust Bowl and deer irruptions and famines.

Leopold developed on this basis what I will call a "contextual" approach to environmental management. Each management problem should be considered in two ways, first as a cell and second as a cell-in-context. At first Leopold thought deer-wolf-hunters was a manageable cell in the system; but he learned that in the arid conditions of the Southwest, it was not. He had also to pay attention to "the mountain," the vegetative cover that gives structure, complexity, and a certain type of stability to ecological communities. Leopold, building on Elton's theoretical conception of a community, concluded that we must always manage any species in its context, that is, as a member of an ecological community. Management will not be considered adequate if the activity decreases the complexity of the contextual system (causes "illness" in the community). Under these conditions, the larger system is in danger of destabilization (such as on the deer-infested mountain).

Leopold's insight was to use organicism as a metaphor to explain that cells in the mountain "organism" change on a slower scale than do management choices of managers when they think in terms of market forces demanding hunting opportunities. He proposed, in effect, that ecological theory, not economics, be embraced as the comprehensive language of environmental management. Accordingly, he groped toward a biologically based criterion of "ecosystem health." Such a criterion would protect the ecological communities that provide the context for systems (cells) that produce resources desired by people. Leopold's criterion, much quoted but—I am convinced—little understood, is: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold 1949, p. 224-225). I am suggesting that integrity is the most important aspect of this criterion, and that Leopold had set as his goal of management to protect the complexity of larger systems.

Leopold's elegant theory was unfortunately impossible to apply, given the state of development of ecological theory in his day. Although Eltonian ecology provided a general framework for conceiving species and complexes of species as embodied in a larger, contextual community, it lacked an adequate conception of stability

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[2]This essay (Leopold 1939), an extremely important one, represents a summary ofwhat Leopold had learned about environmental management. He applied Elton's community model, emphasizing the role of species as vehicles carrying energy through the pyramidally organized community.

as applied to the dynamic system of nature. Leopold's theory required a dynamic conception of stability, one capable of relating a resource-producing subsystem to its larger, dynamic context. This concern for dynamics is what led Leopold to emphasize health and integrity of ecological systems.

He recognized the problem clearly and argued persuasively, in 1939, that the equilibrium model was inadequate to the complexities of management. He warned that a static conception of balance of nature cannot successfully model natural systems:

> To the ecological mind, balance of nature has merits and also defects. Its merits are that it conceives of a collective total, that it imputes some utility to all species, and that it implies oscillations when balance is disturbed. Its defects are that there is only one point at which balance occurs, and that balance is normally static.
>
> —Leopold 1939, p. 727

Management must be conducted with an eye on the larger context, which is expected to change and develop in its own frame of time. Inadequate management of a cell can cause destabilization of the context. As Leopold emphasized in "Thinking Like a Mountain," these interlocking systems embody differing scales of time-the mountain must think more slowly than the hunter or the deer, and the environmental manager must think like the mountain to manage deer-hunter interactions in their larger context. Stability and health in nature must be measured in ratios, by comparing rates of change. Lacking a serviceable conception of dynamic stability of larger systems in which management units are embedded, Leopold's management theory was disabled and remained speculative.

Leopold, nevertheless, launched into a discussion of ecological systems as energy pyramids and argued that "each species, including ourselves, is a link in many food chains." Leopold then notes that "the trend of evolution is to elaborate the biota," to make it more complex and to multiply the channels through food chains by which energy flows to the top of the pyramid. Contextual management conceives the context of management cells to be the larger ecosystem in which the cell is embedded. It remains healthy only if the energy flows in the pyramid remain open and vigorous. This elaborated biota, Leopold described as:

> a tangle of chains so complex as to seem disorderly, but when carefully examined the tangle is seen to be a highly organized structure. Its functioning depends on the cooperation and competition of all its diverse links.
>
> —Leopold 1939, p. 727-28

Leopold, stymied in his attempt to develop positive prescriptions based on ecology, did the next best thing. He fell back upon his governing organicist metaphor and an analogical implication drawn from medicine: lacking a cure for the disease, practice preventive medicine. Caution and humility should, he concluded, guide environmental managers. If you cannot fix the complex system emerging through time, avoid breaking it.

Human changes differ from evolutionary changes, he said, which "are usually slow and local." Leopold therefore distinguished between management activities that are sufficiently violent to disturb their context from those that are not—the former interrupt the energy flows of the community in which they are embedded, the latter do not. He said:

> The combined evidence of history and ecology seems to support one general deduction. The less violent the man-made changes, the greater the probability of successful readjustment in the pyramid.
>
> —Leopold 1939, p. 728

Leopold was therefore struggling toward a dynamic conception of ecological stability, health, and integrity. His tentative contextual model would emphasize complexity, the ecological processes that allow ecosystems to perpetuate themselves, rather than diversity itself. By returning to organicism, Leopold was proposing a new conceptualization of the goals of contextual management: to protect the autogenic functioning—the self-determination—of the larger system. Economically motivated management is acceptable to that point where trends in the exploited subsystems start to accelerate changes in the larger, slower moving system. A system that is losing complexity rapidly as a result of pervasive and violent changes in its subsystems is ill. But here ecology failed Leopold. The fledgling science had provided no quantitative measure, or even a clear qualitative conception, of autogenic functioning.[3] Little progress has

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[3]The most significant developments since Leopold's death have been applications of information theory and systems theory to ecological systems; see Margalef (1963). Also, see Ulanowicz (1986) for an excellent explication of the self-organization of ecological systems.

been made, since Leopold's day, in applying dynamic conceptions of stability and integrity to actual management practices and, until recently at least, little more has been learned about how to relate processes that occur in different frames of time

Recently, however, a new and highly promising theoretical approach, "hierarchy theory," has emerged within ecology; it bears striking resemblance to Leopold's community model and contextualist approach to management. Hierarchy theory, which shows promise to give more precision to the concepts that plagued Leopold's theory of environmental management, is based on general systems theory. It focuses not so much on the diversity of systems as on their complexity and internal organization—what Leopold called "integrity" (Leopold 1949, p. 224).

According to hierarchy theorists, natural systems exhibit complexity because they embody processes occurring at different rates of speed; generally speaking, larger systems (such as a community) change more slowly than the microhabitats and individual organisms that compose them, just as an organism changes more slowly than the organs and cells that compose it. Further, the community survives after individuals die and, while changes in the community affect (constrain) the activities of the individuals that compose it, the individuals themselves are unlikely to affect the larger system because the individual is likely to die before the slow-changing system in which it is embedded will be significantly altered by its activities.

This is not to say that elements have no impact on systems that provide their context. The elements, often called "holons" in the context of hierarchical analysis, are "two-faced"; each holon "has dual tendency to preserve and assert its individuality as a quasi-autonomous whole and to function as an integrated part (of an existing or evolving) larger whole" (Koestler 1967, p. 343; Allen and Starr 1982, p. 8-10). As a part, the holon affects the whole, but scale is very important here—the "choices" of one element will not significantly alter the whole—but if that part's activities represent a trend among its peers, then the larger, slower changing system will reflect these changes on its larger and slower scale. One cell turning malignant will not affect an organism significantly unless a trend toward malignancy is thereby instituted.[4] If such a trend is instituted, then the organism might eventually be destroyed by that trend in its parts. Technology, like plows, drift nets, and rifles, permits humans to create more violent and abrupt trends than nature normally experiences. Natural systems, especially fragile ones, can be overwhelmed by such trends initiated by economically motivated human exploitation. Leopold's contextual approach to management, therefore, focused attention not on individual actions, but on broad social trends in the activities affecting ecological systems.

The multiscalar approach of the hierarchy theorists to time and space in ecology is reminiscent of Leopold's metaphorical discussion of differing scales of time and our perception of them in "Thinking Like a Mountain." Hierarchy theory provides a more precise conceptual model for what Leopold called "the land," which was for Leopold a slower changing system composed of many faster changing parts. He explicitly commented that our failure to see deterioration in the land community is due to our failure to recognize that ecological and evolutionary changes take place in a slower scale of time than the scale perceived by people. Agriculturalists and game managers focus on the rapid-change systems that produce annual crops. The mountain, as Leopold explained metaphorically, must look at the value of wolves in a longer perspective (Leopold 1949, p. 133, 206).

In ecology, which emphasizes the interrelationships among systematic elements, hierarchy theory provides a useful tool for analyzing the multilayered complexity of natural systems, and shows promise to model the dynamic relations among their parts. The hierarchical model may begin to point the direction toward a managerially useful concept of dynamic stability and ecosystem health. It can locate this concept in the interrelated functions of fast- and slow-changing systems. Accelerating changes in normally slow-changing systems may indicate deterioration—illness—in the land community or, perhaps, in even larger systems, such as the global atmosphere.

If a pervasive trend in environmental management can be identified today, it is toward a more holistic, or at least more contextual, management model. For example, in the "Foreword" to its brochure on Chesapeake Bay management, the Environmental Protection Agency writes:

> The Bay is, in many ways, like an incredibly complex living organism. Each of its parts is

[4] Note, however, that changes in the abundance of some species—keystone species—in an ecosystem may have a profound effect on thelargercommunity.

> related to its other parts in a web of dependencies and support systems. For us to manage the Bay well, we must first understand how it functions.
>
> —EPA 1982[5]

The most acute current problem in managing the Bay, the algal blooms resulting from too much run-off from lawns, fields, and pastures, can then be interpreted as rapid change in a normally slow-changing system. This change, according to the model, results from accelerating changes in residential development patterns, agricultural production, and consumer taste. Farmers, homebuilders, and fishermen tend to choose according to short frames of time, seeking, as Leopold said, "peace in [their] time."

Leopold's contextual model for environmental management, with or without the formal elaboration furnished by hierarchy theory, helps us to understand long-term concerns in management of natural resources, including fisheries. As an extreme example, take the "blackened redfish" case. A recipe, originated by New Orleans chef Paul Prudhomme, gained so much popularity that demand for redfish exploded, forcing Louisiana to ban commercial taking of redfish from mid-January to September 1988.

Acting on economic motives and in response to a rapid trend in public tastes, fishermen concentrated their efforts on catching redfish, for an ever-expanding market at highest-ever prices. They acted in the rapid-change system that changes on a human scale of time. But redfish populations were decimated by this rapid change. Leopold's model interprets this result as an example in which the maximization criterion of economic management must yield to limits defined in terms of the biological abilities of the larger system to produce redfish.

This example also explains a unique feature of Leopold's contextual ethic—it concerns tendencies and trends, focusing on intergenerational trends in populations, rather than on actions that affect individuals. Leopold's Land Ethic is systemic, not individualistic—it is not wrong to eat redfish—it is wrong to eat them into extinction because of a runaway trend in consumer fashions. The goal of environmental management is to protect the larger context, the system that supports the fishery, and this requires attention to relations among populations, not individuals. Management concern on this larger scale emphasizes protecting the intertemporal "integrity" of environmental systems.

Distinguishing "resource management", which looks at resource use problems in economic time, from "environmental management," which looks at them in ecological time, may thus be useful. Aggregative analyses and productivity criteria usually guide resource management. Trends in short-cycle management patterns, however, can overbound normal parameters of change in their larger, ecological context, which normally fluctuates and changes gradually through intergenerational time. On this environmental scale, the criterion is not economics, but ecological assessments of the integrity of larger systems.

Having argued that Leopold opted for a contextual management model—a model that can be given more precise formulation in terms of hierarchy theory, one that implies ecologically formulated constraints on economic activity—I wish now to argue that Leopold's intergenerational model suggests also an intergenerational ethic. A contextual model would place limits on economic activities that destroy or disrupt the larger, normally slow-changing, environing system that perpetuates those activities through time.

Standard economic models are ill-equipped to account for these constraints because they discount costs and benefits across time, to express all values in present dollars. This methodological approach to time preference reduces to negligibility any concerns for intergenerational impacts of present activities. A contextual, hierarchical model, on the other hand, suggests that costs and benefits will be calculated within cells of a larger system, which might imply limitations based on the need to maintain reasonable stability of populations (interpreted as slower scaled changes in environing systems) across generations.

What is needed is a "moral filter," corresponding to the mathematical filters of hierarchy theory. John Rawls, in his infinitely fertile treatise *A Theory of Justice,* suggests such a moral filter, which he calls the "veil of ignorance" (Rawls 1971). Imagine a rational, self-interested individual, Rick, who chooses the general rules for a just society, knowing that he will have to live in that society subsequently. Rick, not knowing the specifics of his

[5] For another example of contextual approaches to management, one applied to protecting old growth and biodiversity over the entire region of the Pacific Northwest, see Harris (1984).

social standing and endowments, will design a society fair to individuals of any standing and varied endowments. In fact, the veil of ignorance is many veils. By varying Rick's knowledge, we can filter out individually motivated interests based on such attributes as gender, class, and economic status.

For our present purposes, we can place Rick behind a veil of intergenerational ignorance—he must design a society that he would be willing to live in without knowing the generation in which he is going to live. Now, if he worries that species can be irretrievably decimated by culinary fashions, he will design a society that constrains social and economic trends that tend to destabilize its larger environmental contexts.

If it turns out that Rick is born into a primitive society, or even European medieval society, the intergenerational environmental constraints may seem to be minimal; with hindsight and improved scientific monitoring, however, we can say that conformity to these constraints may have protected the countryside in Greece and China, for example, from the disastrous effects of deforestation and erosion and the inland fisheries from decimation by dams. Contextualism understands moral obligations to land systems in a historical context and emphasizes that, given our knowledge of ecological fragility and our powerful technological capabilities to alter those systems, a generation such as ours has special obligations. As Rick foresees a society such as our own, which alters nature rapidly and has available frightening models projecting cataclysmic changes in the environmental context, he would expect that society to question the moral acceptability of such violent impacts. He would choose a society that would struggle to delineate parameters and thresholds, based on their best models of biology, ecology, climatology, and so on.

These parameters and thresholds would, in turn, imply constraints on trends in individual behavior that threatens to accelerate destabilizing changes in a normally slow-changing environing system. From a moral viewpoint, these constraints would represent "fair" treatment of future generations—the treatment a rational, self-interested chooser would insist upon if he did not know which generation he will inhabit.[6]

[6]In this way, we can understand fairness across generations without introducing the metaphysically puzzling notion of "rights" of future generations. See Norton (1982).

When environmentalists accept an obligation to future generations, they do not see it as an obligation to any particular individuals; the relationship occurs at the interface of two systems—human economics, demography, and so on, with geophysical, biotic systems. With this view, environmentalists believe that biological and climatological constraints exist that correspond to the moral constraints limiting the extent to which any generation could fairly degrade the world's resources. Believing this, it is not surprising that environmentalists also believe that people are morally required to undertake stabilizing actions when projections show that trends in individual behavior threaten a biological or climatological threshold, and institute accelerating changes in the environing systems.

These obligations are viewed holistically, organically—they are owed to the future, just as we owe our forefathers, not individually but collectively, for our cultural heritage; these obligations derive from a faith in the value of the human struggle and from the conservative idea of Edmund Burke that a society represents "a partnership not only between those who are living, but between those who are living, those who are dead and those who are to be born" (Burke 1910, p. 93-94).

Environmentalists' moral intuitions that we ought not to destroy a fish stock to cater to momentary fashions, nor should we overheat our atmosphere by releasing, in a few decades, all the carbon stored in fossil fuels over millennia are not based on a balancing of future winners and losers, however. Rather, they are based on the belief that we ought not to destabilize the normally slow-changing systems on which the daily activities of many generations depend. In this sense, I conclude that in contextual environmental management—management that is sensitive to the importance of trends in whole populations across ecological scales of time—economic considerations become ethical considerations.

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Is Sustainability Attainable?

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People adapt to a wider range of habitats than any other animal because of culture. Culture, which includes the values and behaviors about economic enterprise and ecological practice, can also sow seeds of self-destruction. In Western culture, economic and ecologic values have been increasingly at odds with one another.

One view is that economic growth is necessary to promote progress and prosperity. Those looking at altered environments stemming from economic growth worry that continued diminishment of resources, loss of species, and degradation of habitats threaten the sustainability of society. The resolution of these apparently contradictory economic and ecologic views is at the heart of achieving sustainability. Those promoting progress argue economic growth is needed to fulfil pressing environmental and economic needs. If prosperity requires economic growth, then sustainability is not primary. The future would depend on adapting to the changed environments necessary to continue economic growth. Those promoting sustainability predict human society will not persist without stopping thedestruction of resources and habitats.

Since the 1930s, maximum sustainable yield management of fish and forest resources gave hope for maintaining environmental quality while also producing sustained growth (Mason and Bruce 1931, Russell 1942, Steen 1984). Subsequently, "sustainable" has become a modifier for agriculture, development, economics, energy, environment, fisheries, forestry, futures, growth, livelihoods, and world. Most meanings ofsustainability suggest being able to continue living in a habitat or using a resource in the same way well into the future.

Experience of Fisheries as a Model

Fishery scientists have a half century of experience with sustainable yield management (Larkin 1977). Maximum sustainable yield is institutionalized in legislation establishing fishery management practices. Maximum sustainable yield is, "the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions" (Ricker 1975:4).

Sustainable yield management has been successful in few fisheries. Most fish stocks are overfished and continue to be fished at higher rates than biologists think can be sustained. Why after 50 years of sustainable yield management are fish stocks in such poor condition'?

The answer lies in the culture within which sustainable yield management is practiced. Because of the cultural priority given to economic growth, sustainable yield management is a continual struggle to hold off the environmental threats posed by economic growth pressures. Fisheries, then, represent on a smaller scale the problem society faces as a whole. If sustainable yields cannot be achieved for fisheries, where knowledge is usually good about what it takes to attain sustainability, then how will sustainability be successful in much more complex systems?

Growth, Productivity, and Distribution

Western economic values promote growth and productivity. These values propel Western cultures on a path of rapid material gain, but thwart a course toward sustainability. Economic growth forces come from the basic assumption that satisfaction increases with quantity. Increased productivity—getting more outputs with fewer inputs—in Western cultural beliefs is key to improving people's well-being. The benefits from economic growth and productivity get distributed quite inequitably. The push for rapid growth, promotion of productivity gains, and the resulting distributional inequalities obstruct attaining sustainability.

Growth

Classical economics rests on a utility function that assumes satisfaction increases with quantity. Although satisfaction does not increase with more pollutants, toxins, and waste products, individual and organizational behavior typically bear out the assumption that people prefer more, rather than less. The daily competition between individuals, agencies, and firms to increase their gross product shows the preference for more. Who prefers lower compensation and less acclaim? What state agency in the legislative process of fiscal resource scavenging is comfortable with a declining budget? What individual or firm is satisfied with fewer financial resources and less influence? Western economic values assume that the competition between individuals, agencies, and firms helps in achieving greater productivity.

Fisheries, like all renewable resources, have limits to the quantity that can be produced. When confronted with some physical limit, be it the size of a fish stock, water supply, or habitat availability, the first inclination of those who promote economic growth is to get around the constraint and provide more. Typically, one solution for deficient fish stocks is augmentation. For example, increase the stock size by raising recruitment and growth or by reducing predation and competition. Action to overcome limits captures more popular support than accepting limits. Even so, stock size eventually reaches some constraint past which additional increase is not attainable.

If technology to increase supply does not work to raise quantity, another alternative is substitution. People seek to find something that is more abundant and can replace the item in short supply. The ideal for a substitution is that it should perform as well or better than the original and should be of lower cost, be it hatchery for wild salmon, plastic packaging for paper, ceramic magnets for metal, silicon sealants for rubber, plastic ornamentation for chrome, or glitter for gold. Relative to the issue of sustainability, substitutions mean giving up streams protected by old growth for silviculture and salmon for electricity. Substitutions commit some plants and animals to extinction to pursue economic growth.

In fisheries, limited-entry programs have been a mechanism to control growth in fishing effort, but fisheries still suffer from excess fishing capacity and fish stocks are still in jeopardy. Several reasons explain the poor results. First, matching the numbers who can fish to stock size is politically very difficult. Second, productivity improvements reduce the effectiveness of limited entry programs. Even with the same number fishing, improved catching ability means the same number of people take more fish.

Limiting entry is an input control on the number fishing. An alternative is output controls on the amount of fish caught. These controls do not work any better because of social and political pressures to raise harvest quotas and because of errors in calculating the quotas too high. Attempts to create property rights in fish stocks, too, fail to solve the problem. Short-term economic incentives favor exploitation and not long-term protection (Krautkraemer 1988, Clark 1990). In timber, the private lands were overcut before public lands. Attaining sustainability has been no more successful in forestry than in fisheries (Regier and Baskerville, this volume). Classical economics emphasizes not just the amount of growth in resource output but also the rate of growth.

Fast economic growth is held out as an example to follow. Economic policy makers highlight those communities, industries, and nations with the highest economic growth rates. The quest for growth, however, yields two questions: How does growth improve social conditions? and, If growth is necessary, what rate of growth is best? That is, why is 10% better than 5%, 1%, 0.5%, or 0.05%? Is growing as fast as possible the best rate? Experiences with rapid asset growth in banking, sales growth in business, and program growth in government show rapid growth is not inherently good. If economic growth is desirable, perhaps greater concern should be given to finding an optimal rate.

What might be the optimum growth rate? Economic growth might be viewed like a speed limit. The rate of economic growth depends on road conditions. As a general rule, the larger and more complex the system, the slower the safe growth rate. Small and simple systems can grow rapidly because their parameters and the interaction effects are better known.

With human life expectancy at 75 years, having some idea of what could be expected in the next two generations or a person's lifetime is a reasonable time horizon for considering the implications of growth. Let's assume material goods double in the next 75 years. The doubling of consumption in 75 years requires a sustained economic growth rate of 1% a year. If population grows at 1% and people's preferences do not change, then all the gain in material well-being merely satisfies the increased number of people, and the average well-being does not change. The world population growth rate since 1850 averaged about 1.2% per year (Westing 1981). National economic growth rates from 1965 to 1988, as measured by gross national product, averaged 1.5% (World Bank 1990:179). During the same period, however, population growth rates were about 2% (World Bank 1990:229). When population is growing more rapidly than the economy, aggregate well-being decreases.

National economic systems are large and complex. They should grow slowly. Growth having important effects on ecosystems should be slowest of all. In ecosystems, the feedback loops are very complex. Interactions can be masked, and the linkages between components of ecosystems magnify some of the changes. Taking ecosystem factors into account, would reducing planned national macroeconomic growth rates by a factor of ten improve the probability of achieving sustainability? Rather than trying to push national economic growth at 5%, would maintaining it at 0.5% be a more prudent goal? Slower growth rates lengthen the doubling time. A 0.5% versus 5% growth rate lengthens the doubling time from about 14 years to 139 years. With growth at a rate of 0.5%, it takes practically two lifetimes for a doubling and allows time to adjust to the impacts of growth. If economic growth is slowed, so too must population growth be slowed. To improve well-being, the population growth rate should be half or less of the economic growth rate.

No one is clear on the mechanisms by which economic growth helps people live better and solves environmental problems, nor do they measure the results. The typical argument is that economic growth allows environmental degradation to be repaired and poverty to be alleviated. By what mechanism is the gain in net product transformed into restored habitats and enhanced well-being? Rather than accepting the assumption that growth helps solve problems, proponents of economic growth need to demonstrate how the results actualiy occur.

Gross indicators—like amount of fish caught, dollars of catch, and more people choosing to fish or live in a place—are used to show a healthy community. National economic growth usually is measured with a general measure like gross domestic or national product (GDP or GNP). Gross indicators, especially GNP, have often been criticized as measures of economic health. In Daly and Cobb's (1989:62-84) critique of GNP as a measure of economic success, they point out that increased consumption of resources shows up on the asset side, not as a liability. The GNP is not adjusted for the long-term costs of stock rebuilding, habitat restoration, waste disposal, toxic waste clean-up, curing environmental illness, or improving air and water quality. Like the GNP, businesses refer to assets or sales volume as gross indicators of success. Raw growth in numbers of people, sales, or units produced may not yield any net benefit and can even cause a loss. These numbers are not measures of real economic success.

Daly and Cobb (1989:401-455) suggest the Index of Sustainable Economic Welfare as a better measure of economic well-being. This index corrects for some of the problems in traditional GNP measurement of growth. For the period from 1968 to 1986, U.S. per capita GNP showed a 37% growth in constant dollars. The per capita Index of Sustainable Economic Welfare, also measured in constant dollars, showed a 9% decline.

As a measure of growth, GNP is achieved by using up capital resources to give the illusion of economic growth. It is no assurance of long-term sustainability.

Productivity

Coupled with generating greater quantities through growth to raise people's satisfaction are improvements in productivity—generating more of something with the same or less effort. In Western economic values, productivity equates with economic efficiency where the benefits from an activity should exceed the costs.

Anthropologist Marvin Harris discusses the biopsychological behavior of humans. Harris sees both growth (getting more) and productivity (getting more with less effort) as part of the basic human makeup. In identifying these basic assumptions about the human enterprise, Hamis (1979:62-63) says:

> People need to eat and will generally choose diets that offer more rather than fewer calories and proteins and other nutrients.

> People cannot be totally inactive, but when confronted with a given task, they prefer to carry it out by expending less rather than more energy.

Western economic values complement these drives. Economic policy makers argue that productivity is crucial to elevating people's well-being. The Brookings Institution (Nourse et al. 1934:3) proposed that if the U.S. economy were modified to increase productivity to pre-Depression rates,

> . . . every citizen who cared to exert himself could attain a material standard of living equal at least to that of the so-called "middle class" in the prosperous days before the collapse of 1929. . . .

The message that well-being only improves as productivity improves is a persistent economic policy theme.

Theoretically, productivity gains should create more for society while also promoting conservation. The problem is in knowing what choices will achieve productivity goals. Since the 1930s, benefit-cost analysis has become increasingly part of decision making to exploit resources, alter habitats, and make ecological modifications. Benefit-cost analysis weighs where society gets a greater benefit for some expenditure. Such benefits generally equate with quantity without qualitative distinction.

Benefit-cost analysis is subject to much criticism. Bromley (1990:97), for example, notes:

> Curiously, the identification of benefit-cost analysis with efficiency via Pareto improvements has come despite overwhelming evidence from within economic theory of the logical fallacies inherent therein.

Norgaard and Howarth (1990:5) point to an inherent weakness of benefit-cost analysis as done by neoclassical economists by pointing out:

> The problem is that when they undertake benefit-cost analysis, they forget their other demand curves are constantly changing. If demand curves are constantly changing, values are constantly changing. And if they are changing in ways which are neither random nor predictable, values over the period of economic decisions cannot be determined.

Benefit-cost analysis rests on the assumption that current social values will persist into the future. For example, in the 1980s, the Northwest Power Planning Council rested its salmon recovery plan on increased production from hatcheries. People's values changed, and in the 1990s, protection of wild and endangered salmon runs received priority.

Fisheries are particularly sensitive to productivity growth. People who fish continually try to catch more fish with the same or less effort. For a resource at its maximum sustainable yield, this means people who fish continually get better and place more pressure on a limited resource. Even with limits to the number of people fishing or their catch, those still fishing continue to improve their ability to catch fish. Productivity improvement is one way to gain an edge over competitors. Because the people who fish constantly improve their productivity, fishery managers continually fall behind in limiting fishing effort to attain the maximum sustainable yield.

In a fishery at the maximum sustainable yield, productivity gains will improve well-being only if the number of people fishing decreases. If the number of people fishing stays the same and the fish resource is at the maximum sustainable yield, the productivity gain of one person becomes a loss for another. The implications of the fisheries experience in a sustainable system is that the number fishing must decline for productivity gains to increase net well-being.

Distribution

Distribution is the third factor making the attainment of sustainability difficult. How are the benefits from growth and productivity improvements distributed? Who are the beneficiaries?

Correlated with overfishing is greater inequality among those catching fish (Smith 1990). In commercial fisheries, the number of people needed to take the catch decreases. In 1899, the top 5% of salmon gillnetters caught 12% of the salmon. In 1971, the top 5% caught 47% of the salmon. As the Oregon bottom trawl fishery grew very rapidly from 1976 to 1980 and average catches declined, the top 5% of trawlers increased their share of the catch from 15 to 26%. As the number of people fishing with very low catches becomes larger, many of those with low catches have difficulty just maintaining their current situation. Focusing on immediate needs prevents people from considering the long-term sustainability of fish stocks.

For resource managers, greater inequality in catches causes several problems. First is numbers—the problem of regulating many people with small catches. Second, greater inequality and more regulation increase the inclination to cheat and poach. More catch is taken illegally, outside the purview of management. Third, with inequality, people become driven to meet their basic needs. Fishing becomes obsessive as more and more fish must be captured to meet mortgage and boat payments, satisfy basic needs, and just break even. Finally, divisions among participants created by inequality segregate those fishing, and they begin to prey upon one another in the management process. Inequality promotes environmental scavenging. Rich and poor seek to satisfy their needs and degrade habitats without much regard for the future.

Achieving sustainability depends on having a concept of the future. Poverty shortens people's future orientation. The poverty facing many of the world's people threatens to topple any attempt at sustainability. A fifth of the world's population, mostly children and their mothers, go to bed hungry each night (World Bank 1990). The current demands for basic survival to provide food, housing, and health care outweigh the ability to look ahead.

When the daily task is meeting basic needs, the tree cut down or the fish taken do not enter people's long-term calculations. The poor person's problem is surviving today, for if enough food is not found, or shelter does not protect against the heat or cold, or if adequate health care is not available, there is no tomorrow.

People can only contemplate tomorrow when they are well-fed, adequately housed, and healthy; otherwise, what is the meaning of sustainability? From the viewpoint of someone who has a future sustained by adequate food, housing, and health care, destruction of resources is shortsighted. From the point of view of poverty, today's survival is the top priority. The whole issue of sustainability is beyond the time horizon of poor people.

If economic growth solves problems of poverty, its record is subject to question. Productivity improvement should generate the real gains to improve people's well-being, but poverty rates show no evidence of having improved to any significant degree.

Micro Principles and Meta Concerns

Many have noted that ecology and economy both derive from the same root—meaning household. Ecology is the relation between the members of the household and the environment of the house. Economy is household management. Economics encompasses the relations between those within the house—individuals, firms, resource owners, nations. As commonly used, economics is deductive, deterministic, propositional, and particular.

Economics looks at the household from macro and micro perspectives. Macroeconomics deals with production, prices, employment, and monetary policy of aggregates like nations. Microeconomics focuses on individuals, firms, and resource owners. Too often, when resource managers consider ecological problems, narrow concerns control considerations about the ecological system. Individuals, firms, and industry organizations pressure resource managers to relax concerns for the ecosystem. Letting principles about maximizing economic efficiency filter up to influence the ecosystem fosters narrow, short-term, microeconomic perspectives when the need is to be holistic, systemic, and synthetic (see Norton, this volume).

Ecology needs to be long-term, holistic, and meta. The first-order question is the suitability of the ecosystem to support life. Ecology, as a meta concern, gets lost with the application of the short-term economic focus on growth and productivity.

The popular presentation of economic principles suggests that individuals and firms who are maximizing economic efficiency will generate economic growth that allows ecological problems to be solved. Prolonged experience shows that maximizing economic efficiency also depletes resources, threatens habitats, and causes ecological problems.

Resource management has become dominated by microeconomic considerations. The linkage between fishery biology and economics—bioeconomics—began with the recognition that the fisheries model for population growth and harvesting is logically the same as the economic model of capital growth and consumption (Gordon 1954, Schaefer 1957, Crutchfield and Pontecorvo 1969, Clark 1990). Microeconomics is very good for explaining the success and failure of fishing firms. Maximizing net present value is an important decision-making criterion for the individuals and firms. Maximizing economic efficiency stimulates competition and encourages innovations.

Microeconomic priorities, however, keep resource managers from making the hard decisions required to sustain fish stocks. Unfortunately, the profit formula only includes known current costs and looks at immediate benefits. Maximizing economic efficiency does not account for long-term costs, nor does it look at the impacts of short-term profits on the whole ecosystem; further changes in people's tastes and preferences are not considered.

Adapting to our ecosystem is a meta problem. It requires a more holistic, integrative, and long-term perspective. Microeconomic theory asserts that the logic of maximizing economic efficiency is complementary to maximum sustainable-yield management. The practical result, however, is ever-increasing destruction and devastation of the ecosystem. Profits explain the success of firms, but not the persistence of ecosystems. What is good at the microeconomic scale is not necessarily what is needed at the meta ecosystem scale.

The relation between macroeconomic theory about national monetary policy and the microeconomic behavior of firms illustrates how different scales of theory operate. During times of inflation, the monetarist wants to hold down the growth in currency, which drives up interest rates, increases unemployment, and causes some firms to fail. Higher interest rates make getting the capital necessary for expansion more difficult. Higher unemployment hurts workers. Yet the macroeconomic policy of the monetarist has priority over the microeconomic needs of individuals and firms because the health of the national economy is more important. If ecosystem sustainability is to work, ecological policy needs priority over macro and microeconomic decision making.

Alternatives

Fisheries provide a model of how ecological and economic values interact in society as a whole. Fisheries represent in more manageable form the problems facing Western culture as a whole. But what can be done?

One choice is to continue as in the past; that is, accepting our addiction to economic growth, recognizing that sustainability is not attainable, and living with constantly changing environments. Continuing the pursuit of economic growth, as the solution to problems of economy and ecology, means persistence of past patterns of extinction for species that cannot survive ecosystem modifications. Support for the durability of past practices is found in Simon (1980,1981) and Simon and Kahn (1984), among others.

A second choice is to change the value foundation and develop sustainable economic and ecological paradigms; that is, move away from economics solely concerned with maximizing economic growth. Bioregionalism and Gaia [Gaea] (Sale 1985, 1986; Lovelock 1979, 1988), steady-state economics (Daly 1977, Daly and Cobb 1989), the Genesis Strategy (Schneider 1975), Buddhist economics (Schumacher 1973), rights of future generations (Norgaard and Howarth 1990), and ecologically centered values (Leopold 1949; Berry 1975,1981, 1989; Devall and Sessions 1985) are possibilities. Each requires new values upon which society bases decisions. These values require weaning from addiction to economic growth as the problem solver.

A third choice is to make some relatively simple changes to the Western practice of political economy. The World Commission on Environment and Development (1987) proposes controlling population growth, while using improved productivity to address inequalities among peoples. This goal involves setting a speed limit, particularly for economic growth. If growth and productivity are deeply rooted in the human condition, we need to acknowledge this. If growth and productivity are fundamental human needs, new paradigms and value changes may be quite difficult to effect. Retain the microeconomic, market-oriented values of classical economics, but require that growth and productivity operate within the ecological constraints required to achieve system sustainability. This approach requires actually measuring whether real economic growth is taking place, assessing what activities increase productivity, and analyzing how the benefits become distributed. Most of all, this approach requires a much longer planning horizon, something on the order of a lifetime, 75 years.

Adopting this third approach raises distribution as the issue of primary concern. A sustainable ecology must make distribution the first consideration. Bromley (1990:91) notes how the Western economic paradigm separated production from distribution. Growth and productivity became the sole concerns. Economists assumed that distribution would take care of itself.

The inequality represented in persistent poverty kills future orientation.

I do not presume to know which of these approaches future human societies will take. Western economic values are leading the assault on the environment as we know it. Human survival requires an ecosystem capable of supporting human life.

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Sustainable Redevelopment of Regional Ecosystems Degraded by Exploitive Development[1]

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Introduction

Think Globally, Act Locally

Conventional economic development, which exploits ecological and other features of a locale, is usually undertaken with the aim, among others, that benefits will cumulate and contribute to regional economic growth and to "progress," with some consideration that the people of the locale will also receive some benefit from the exploitation. Local disbenefits, say in the form of bad ecological consequences, also tend to cumulate and to become apparent, eventually, as regional degradation. Whether intended or not, conventional local actions and their consequences tend to cumulate powerfully at regional scales, and thus local actions should be viewed in a regional context, with respect to good and bad aspects alike.

We focus our attention on economic development practiced during recent centuries in North America, but especially with respect to two case studies: the New Brunswick forests and the Great Lakes fish (see fig. 1).

[1] Adapted from. W.C. Clark and R.E. Munn, editors. 1986. Sustainable development of the biosphere. Published with permission of the International Institute of Applied Systems Analysis, Laxenburg, Austria.

Part of the economic development during recent decades in the Third World may resemble, in some ways, the process of North American development outlined here. The resemblance may be weak with some European countries, where renewable resources have not been subjected to so rapid a development pressure and have been managed differently, at least recently.

In his statement on the issues surrounding the "think globally, act locally" philosophy, Holling (1984) uses global in the sense of biospheric rather than, say, of some rather arbitrary level of aggregation. As have others, we have difficulty in demonstrating local-biospheric links, though we "know" that such links are almost infinite in number. We deal in this chapter with local-regional links and submit that our contribution may be seen as a small-scale analog of the issue of links across gaps of larger scale.

From the perspective of an interested layperson, the conceptual link from the local to the regional may involve a connection between relatively concrete local reality and relatively general and somewhat imprecise regional inferences that are comprehensible only as abstract arithmetic summations or mathematical expressions. A link to a biospheric scale might involve a connection to phenomena that may appear so abstract (e.g., computer simulations) as to be almost unreal. How do we demonstrate interactive and cumulative linkages across different scales and modes of cognition in such a way that the new comprehension contributes to the sustainable redevelopment of all these scales within scales? We cannot give clear advice, but we both are involved with regional projects in which attempts are underway to

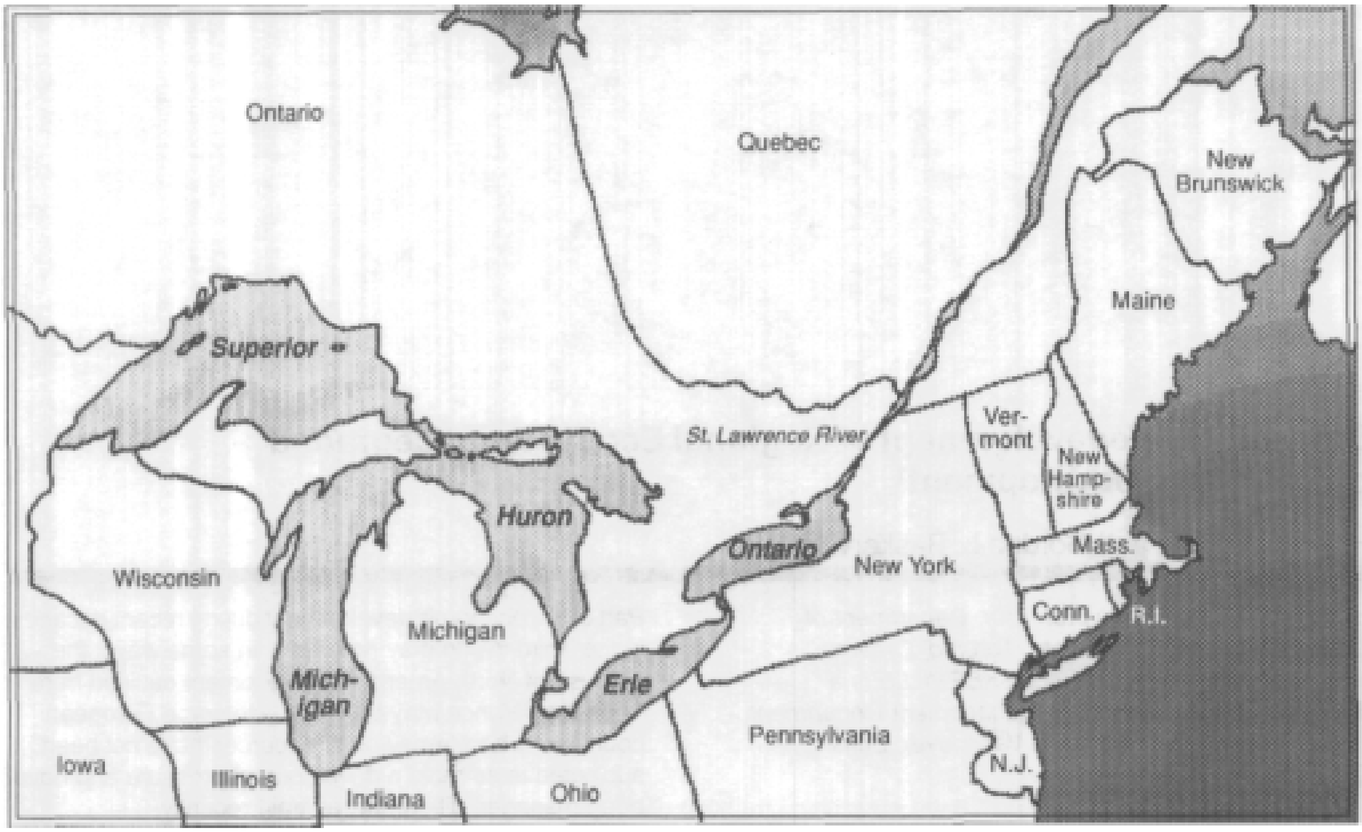

Figure 1—Eastern North America showing the Canadian Province of New Brunswick and the binational Great Lakes.

forge useful links between the local and the regional, to be operative in both directions.

Development and Redevelopment

Within the context of economic development, "to develop" generally means to use available resources in such a way as to achieve local or regional progress through increased economic growth, usually measured by a suitable regional indicator, such as total jobs created, and net value added. Underdevelopment may mean that some resources are not used to their full economic potential, with the result that local or regional economic progress is slower than it might otherwise be. Overdevelopment may mean that some important resources are overtaxed, again to the disadvantage of regional economic progress. Misguided or improper development may mean that mistakes have been made concerning the use of some resources—for example, through the once-only destructive use or sacrifice of a renewable resource important to the sustenance of a future economy. These and other variations on the concept of development have rather close conceptual parallels in the study of the harvest of renewable resources and of the use of the natural environment.

We do not deal with the extraction of nonrenewable resources as related to economic development, except to mention that some general parallels exist in North America between improper and excessive harvesting of renewable resources and improper and wasteful extraction of petroleum and some mineral ores. Both of these major processes, as conventionally practiced, severely disrupted the natural functioning of the affected ecosystem.

We personally experience no euphoria in contemplating recent versions of what is implied in North America by economic development, economic growth, and progress. Nevertheless, these terms are widely used the world over and have been accepted as central to the study of the sustainable development of the biosphere; we can put them to objective use without necessarily endorsing various connotations subjectively. Perhaps we can help to develop a set of connotations for the term sustainable redevelopment that may be acceptable for both objective and subjective purposes.

In many parts of the world, the natural environment and its renewable resources have been misused, overused, and abused to the point of severe degradation. Sustainability for some desirable mix of valued uses has been vitiated in such areas through destructive abuse, overintensive use, or ill-informed practices in general. The only reasonable option in such areas is a redevelopment toward sustainability. Various terms or slogans have been used that relate in some way to a reversal of the degradation, whether ecological, anthropological, social, economic, industrial, or urban—for example, reform, rejuvenation, remediation, restoration, rehabilitation, reforestation, resettlement, reindustrialization, rezoning, renewal, recovery, revitalization. Taken together, all of these terms that are relevant in a region might constitute "redevelopment"; ecological rehabilitation of such areas is obviously crucial, else sustainability is an empty or misleading slogan.

Throughout North America in particular, major aquatic, forest, grassland, and cultured ecosystems have been degraded. Major, though perhaps only partial, American initiatives toward ecosystem or regional redevelopment include the Tennessee Valley Authority initiatives in southern Appalachia, the Soil Conservation Service initiatives on the Great Plains, and regional reforestation in the Southeast. In subsequent sections, we present two case studies of more recent initiatives toward redevelopment: the forests of New Brunswick in eastern Canada and the Great Lakes of central North America. Our cases are similar yet different. The New Brunswick case represents a deliberate provincial effort to redevelop a rural community economy based on forestry before the natural productive base becomes too severely degraded: opinion leaders in New Brunswick have suddenly recognized the associated problems and opportunities. The Great Lakes case represents deliberate international efforts, to date costing perhaps over $10 billion (1985 U.S. dollars), to rehabilitate massively degraded ecosystems, especially those of the Lower Lakes. For various reasons, the Great Lakes industrial and agricultural heartland lost its vitality and vigor, and people recognized that ecosystem degradation was part of the problem. It is now widely expected that successful rehabilitation of these lake ecosystems will have both a direct and a catalytic role in the revitalization of this binational heartland, even though the apparent additional monetary benefits of a rehabilitated chain of Great Lakes may be only a small fraction of the wealth created in the Basin (Thurowetal. 1984).

In both cases, we have greatly simplified the record to enhance understanding. We show that integrated regional redevelopment of degraded systems must be served by appropriate information systems, which must explicitly link the local and regional scales of concern. With respect to spatial and temporal scope and scale, and to detail of resolution, a regional information system obviously falls somewhere between biospheric and ecosystemic information systems. Information systems already exist in some, perhaps primitive, form for the redevelopment initiatives mentioned here. Progress in redevelopment will likely depend on the further creative development and thoughtful use of such information systems.

The Forests of New Brunswick

The setting and a historical sketch—The province of New Brunswick is largely forested (85% of its 78,000 km^2) and has been so in the 10 millennia since the last continental glacier melted. During the past two centuries, the economic development of sparsely populated New Brunswick has depended primarily on the exploitive use of forests and secondarily on the exploitive use of fisheries and agricultural soils. The province has never served as an industrial heartland to any other region, nor is it likely to do so in the future. It is relatively free of the pervasive and massive pollution that attends large industrial and urban concentrations, though the effects of atmospherically transported acid rain and toxic fallout, and of climate warming, all resulting predominantly from the improper and excessive combustion of fossil fuels, will soon become as apparent there as elsewhere.

In this sketch of the history of conventional exploitive development and of opportunities for sustainable redevelopment in New Brunswick, we focus mainly on the forest industry. Consideration of fisheries and agriculture, of human settlements and pollution, and of the outbreaks of the spruce budworm would complicate the account but would not greatly affect the inferences that can be drawn from a simplified account of the forest industry.

The development of the New Brunswick forests has been a long process (Tweeddale 1974, Wynn 1980). In the early 1800s, the forests provided large white pine trees for ship masts, which meant selecting high-value specimens and bringing them out with considerable care. Although this extraction generated a step in the development of the local economy, it was at a very low scale, and the quality of life associated with it was, in the prosaic sense, hardy. But the die for future development was already cast: "For profit is the first motive of all men," as Nicolas Denys (1908), a naturalist-cum-early developer of the early 1700s, wrote in his diary of 1708.

Continued development (read "progress through economic growth") was temporarily arrested by the unavailability of very large, and very old, white pine trees. Development proceeded, however, with the harvest of white pine to less-stringent quality standards to produce squared timbers for building, most of which were exported. This product provided considerably more local employment than did the search for masts and resulted in a modest improvement in the quality of life of the pioneer communities.

One course then taken in the development sequence was to broaden the harvest to include younger trees. If 300-year-old white pine are harvested faster than they are recruited to that age class, the development may be extended by a shift to younger, smaller trees. Successive steps in the development of the white pine industry (fig. 2) began with the high minimum standard acceptable for raw material at point A, and continued until the white pine available were of a size characterized by point B, which then became the acceptable minimum standard.

By the middle of the 1800s, the next major step in the process of development began with the emergence of a major sawmill industry that produced finished timber, again mostly for export. The work contributed "value added" to the product, enabling the local society to gain some additional economic benefits from the resource, but also the regionally based lumber industry gained. To develop this lumber industry further, the source of raw material was again broadened, with changing minimum standards of acceptability, to include not only the remaining large and small white pine trees available, but also the larger white spruce. This change is a movement in the minimum standard acceptable for raw material from B to C (fig. 2). The sawmill industry continued to grow (develop) in a manner that required quality raw material faster than the forest was producing that quality, with the result that the minimum acceptable raw material gradually moved from C to D on the lower curve in figure 2.

The sawmill industry reached its peak in the late nineteenth and early twentieth centuries and has been declining ever since, with the number of sawmills in the

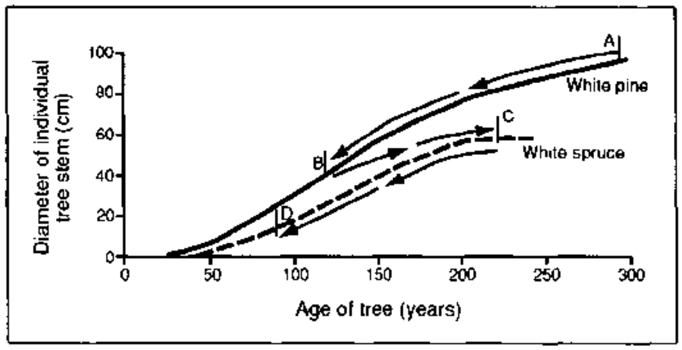

Figure 2—The diameter of white pine and white spruce stems as related to age of the stem. Stem size is a crucial factor in sawmill efficiency. Early exploitation began with white pine at point A, continued using smaller stems until point B, where it was equally efficient to switch exploitation to include large white spruce at C. Continued exploitation mined the largest stems until current limits of acceptability were reached at D.

province today only a fraction of that in the heyday of the industry in the late 1800s. The surviving sawmill industry uses not only the available spruce logs (and the small amount of white pine available) but also balsam fir trees. Currently, the minimum acceptable size for all these species is a fraction of the original.

Although the sawmill industry was developed largely on the basis of individual trees, a pulp and paper industry emerged in the province shortly after the beginning of the twentieth century, an industry based on whole stands of trees. The arrival of the pulp industry happened to coincide with poor lumber markets and the relative non-availability of large individual stems suitable for efficient use in the kind of sawlog operation that had evolved in the nineteenth century. Pulp mills can use smaller trees, although harvesting of larger trees makes for a cheaper raw material. Just as the sawmill development was based on harvesting only the best individual stems and leaving the poor-quality material (highgrading), so pulp and paper development was based on harvesting the stands of best species and lowest logging cost while bypassing lower quality stands (also highgrading). Because of the large wood volumes required by pulp mills, people generally harvested nearly pure stands of the usable species (spruce and fir), leaving behind stands of species not usable for pulp. Pulp mills marked a major development for the local economy, capturing not only a much larger portion of the value of the finished resource by spin-off employment, but also by generating a better quality of employment.

Initially, the pulp and paper industry used stands of smaller spruce trees and, as these became less available, raw material standards were relaxed to include stands of larger fir trees as well. Since the mid-1950s, the industry has adapted technologically so that it can use stands of very small trees of softwood species and some hardwoods. To characterize the impact of the pulp and paper industry on the resource, we examine how these utilization standards relate to stand development—that is, to natural production in a stand. How a particular softwood stand (that is, a population or community of trees) might develop in terms of volume per hectare and of average tree size is shown in figure 3, from its regenerating stages, through maturity, and overmaturity, to breaking up in old age. Combinations of minimum volume per hectare and maximum trees per cubic meter determine the operability or availability of a stand for economic harvest. At the beginning of the development of the pulp and paper industry, only those stands represented by the range A and A' (fig. 4) were considered economically usable. These operable stands had reached both the specified economic minimum total volume per hectare and the specified economic minimum average tree size harvestable, but they had not yet broken up to the point where less than the minimum volume remained, below which it was not economic to harvest. Clearly, when stands of type A-A' were harvested faster than they were recruited to this range, a shortage of material for the mills occurred over time, which could have forced a reduction in their output. Analogous to the case for sawlogs from individual stems, the answer to such a constraint was to change the utilization limits for whole stands to the range B-B' (fig. 4); the advent of a biomass approach suggests extension to the range C-C.

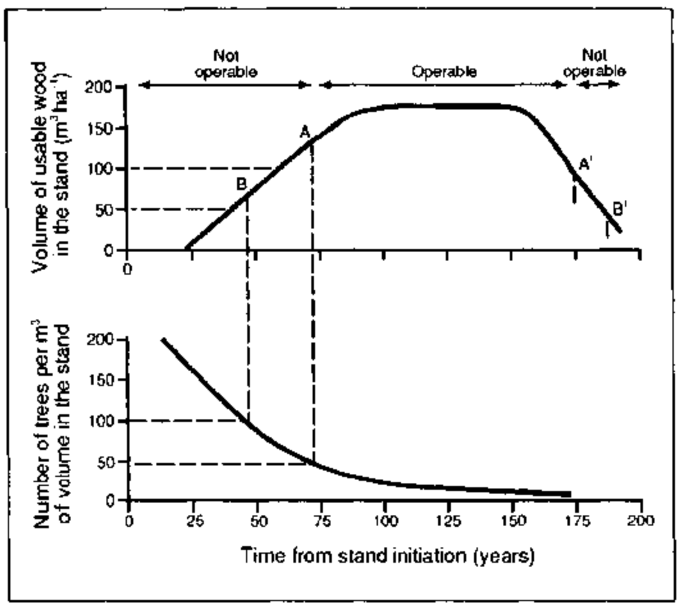

Figure 3—Softwood stand development as seen by the developer. Above: The accumulation of volume over time, showing how much wood is available at various times. Below: Average tree size as it changes over time. Operability constraints work in two ways: (a) the stand must have enough volume per hectare to be worth developing-for example, 100 m^3/ha, and (b) the stand must be made of individual stems large enough to be commercially harvestable: forexample, 5 trees/m^3 give the points A and A', and the constraints of a minimum 50 m^3/ha and a maximum of 10 trees/m^3 give the points B and B' For the first set of constraints, the stand is harvestable (operable) between A and A' and B and B', respectively.

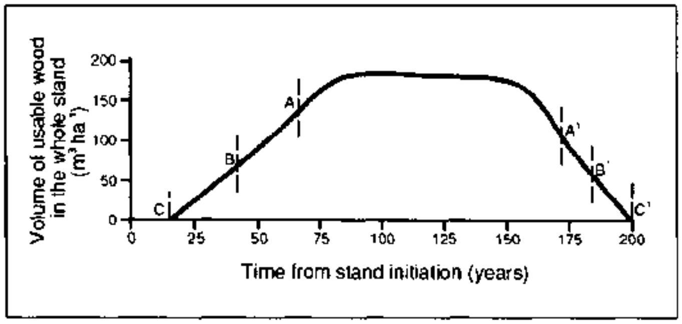

Figure 4—Volume development in a spruce-fir stand. The curve shows the merchantable volume per hectare at any point The ranges A-A' and B-B' are periods when the stand is economically operable The point A is determined by both a minimum volume per hectare and a minimum average tree size. The point A' is determined by the minimum volume per hectare. The stand is operable (that is, eligible for harvest) in the range A-A'. If the operability constraints of volume per hectare and average tree size are relaxed, then A moves to B and A' moves to B'. In this case, the stand is operable for the period from B to B'. The process may continue to some ultimate state identified here by the extremes C and C.

New capital investment and technology—of both hard and soft types—were required to effect a shift from A-A' to B-B'. This shift then permitted further development of the economy in that the broader utilization standards (at B-B') gave an almost instant increase in sustainable production. For example, a harvest of 400,000 m^3/year from a forest was not sustainable when the stand utilization limits were set at A-A', but was sustainable, and could even be increased to 600,000 m^3/year, when the utilization standards were set at B-B' (fig. 5). Further industrial development was possible by harvesting stands comprising several species, only some of which were suitable for pulping (fig. 6). Harvesting in these mixed stands faced similar utilization standards for total volume and average tree size and had the additional logistical problem of working around the trees of unusable species, but it also gave a larger growing stock and a more sustainable harvest.

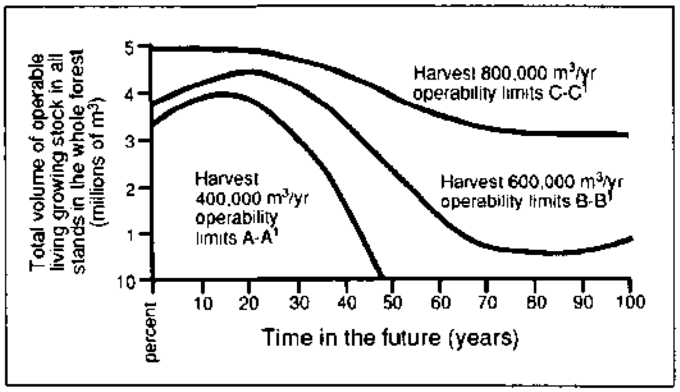

Figure 5—Three reasonably possible futures for the same initial forest, but harvested subject to different operability constraints. Curve A: With operability limits set at A-A' (from fig. 4) the total operable growing stock increases at first, but cannot sustain a harvest of 400,000 m^3/year. The growing stock goes to extinction in the fifth decade. Curve B: With operability limits set at B-B' (fig. 4), the total operable growing stock is larger than in A, and the larger harvest rate of 600,000 m^3/year is sustainable, although the growing stock is driven dangerously low near the end of the forecast period. Curve C: with operability limits at C-C (fig. 4), the total operable growing stock is again larger and the harvest of 800,000 m^3/year is sustainable. Note that the initial increases in operable growing stock are artifacts, in that the wood was always there in case A but was not counted because of the operability constraints. Also note that the apparent gains in sustainable harvest are each achieved by harvesting younger (poorerquality) raw material.

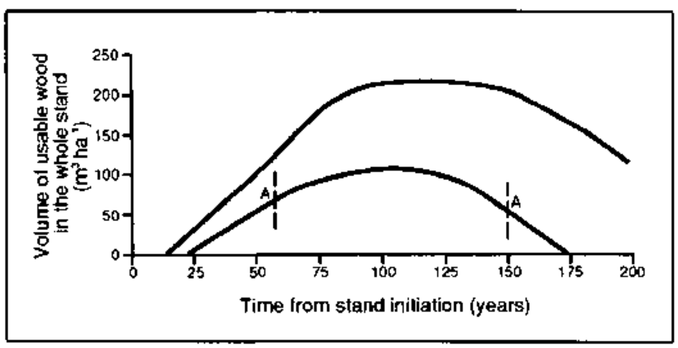

Figure 6—Volume development in a mixed stand where only the softwood volume (lower curve) is usable. The softwood volume is subjectto operability constraints shown in figure 3. When the softwood species are harvested, all or nearly all of the other species are left standing.

As with the pulp and paper industry, the lumber industry also innovated technologically to use less-valued species, smaller trees, and stems of lower quality in the manufacture of such products as laminated beams, plywood, and chipboard. Such innovations are capital intensive and involve advanced technology. In effect, capital and technology are used to mitigate reduction in the quality of the resource.

Examining the conventional saw- and pulp-mill examples of development clearly shows that both constitute forms of highgrading. The lumber industry was built on highgrading individual stems, and the industry declined because of inefficiency when recruitment to these quality standards could not match the harvest rate imposed on the trees of that quality by the highgrading. The pulp and paper industry was built on the principle of highgrading at the stand scale, where whole stands of particular species and size characteristics were removed and the utilization standards lowered from time to time, as necessary, to sustain the development (Swift 1983). In both cases, the forest resource was clearly used to develop the economy. In fact, the use was very effective, in that each step in the process:

- Allocated a larger proportion of the economic benefits to the local society.
- Increased the number of jobs locally.
- Improved the quality of those jobs.
- Improved the quality of life in the local society.

At present, however, New Brunswick faces a situation where further development is no longer possible. In fact, sustaining the forest-based industry will be barely possible even with major forest management efforts of a redevelopment type (Reed 1978).

Exploitive development—Some further consideration of the concept of exploitive development is appropriate at this point. Clearly, without specifications of quantity, quality, timing, and location, the notion of sustainability is meaningless. A sawmill industry has existed for almost 200 years, but no one would claim that product quality was sustained for any significant period within those 200 years. What did survive was an industry that used poorer and poorer quality raw material and was strongly dependent on capital-intensive technological innovation to create a quality product out of raw materials of low quality. A forest industry, broadly defined, was sustained, but the productive structure of the resource was not.

Two points to consider with respect to this resource development are, first, development was not a single step taken to achieve a specified goal, but rather it involved a continuous expansion of local and regional economic benefits, narrowly defined, that became a goal in itself. In this context, for any resource a point in development certainly exists beyond which sustainability is no longer possible because of biological limits of the resource system. The second point really attacks the nub of the issue. Historically, development in resource-rich areas is driven by the clarion call of government, industry, and enterprising people "to develop our resources." Clearly, primarily the resource-based industries are what have been developed, secondarily the regional economy, and tertiarily the local economies—but the resources have not been developed at all. The resources have been characteristically run down or ruined by resource development—surely one of the saddest paradoxes of human activities. Highgrading has been degrading.

In New Brunswick, the forest-based industry may now be characterized as overdeveloped, and the forest resource is in urgent need of redevelopment. The existing economic structure is derived from a sequential lowering of utilization standards and broadening of the target species mix. The existing economy could barely be sustained by a further lowering of utilization standards along with a very aggressive management program, but the limits of development in the traditional economic sense have been reached. The key here is that resource development has been measured throughout this process in terms of the immediate social and economic results and not at all in terms of the productivity of the resource that was used. The resource was used to achieve the development, but using the resource altered its dynamic structure. The resource structure changed with respect to:

- The size and stature of particular species in the stands.
- The species composition of the various stand mixes that were available in the forest.
- The age structure of the stands in the forest as a whole.

Instead of progressive overexploitation of the resource to manage (read "expand") the economy, the resource must now be managed (read "redeveloped") to maintain the economy. Put bluntly, gaining further development or even sustaining the existing rate of development by mining the forest is no longer possible. Maintaining the existing rate is possible with proper management, but any expansionist development must be delayed several decades until the results of new management measures take effect.

Some characteristics of these limits to development are of interest. Perhaps the most striking is that each of the individual development steps took place at the tree or stand scale. Local (tree and stand) actions, which were taken out of context of the regional forest picture, have accumulated to produce an unacceptable regional result. The problem literally was created piece by piece locally, and then recognized and felt regionally. Further, the design of the solution to problems created by development must proceed at the regional scale. The stands that have been highgraded successively for sawlogs now support a mixture of poor-quality stems and unusable species. Harvest of only the usable species for pulping has resulted in an increased occupancy of land by non-economic species. Indeed, the only way left to develop in the conventional way is by moving to a lower grade of product, which will result in a weaker economic position, based on the massive mechanization required to use the very low-quality natural product.

The result of such development has been a dramatic change in the productive structure of the forest. A plausible age structure for the various stands of the forest before development is shown in figure 7, along with the age structure for the developed forest. Conventional development has transformed the productive structure into that of a young forest. Given the present age structure, either the pressures must be relaxed to allow some time for recovery or massive assistance must be given to the natural regrowth of the forest. To achieve some recovery time requires a relaxation of harvesting pressure, which implies a loss of some of the development gained over the last half century. That is not a socially acceptable alternative. Intervention in stand and forest dynamics, to increase the rate of availability of materials, requires major expenditure in terms of forest management. These costs are clearly chargeable to maintenance of the development. Because these costs were not there previously, they substantially reduce the economic value of the accumulated development in conventional economic terms. To hold its own, the province must give up some of its resource-based economic development to achieve resource redevelopment.

Sustainable redevelopment: design and implementation—Discovering overdevelopment is not easy, and designing redevelopments can be downright traumatic. Recognizing incipient overdevelopment is difficult, in part because the necessary information is rarely available until after the event. During the process of non-sustainable development of an economy, data gathering

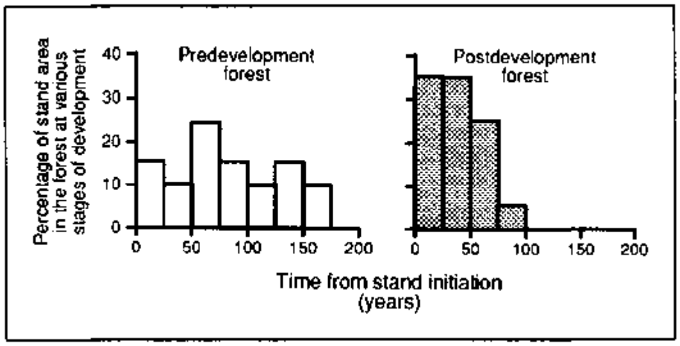

Figure 7—Age-class structures for forests before and after development. The predevelopment forest shows stands at all stages of development when related to the volume development curve in figure 4. The postdevelopment forest has been harvested intensely enough to prevent stands from growing beyond 100 years from initiation. Thus, the stands in the range 100 to 160 years, which would contain the largest individual trees, are no longer present.

with respect to the resource is centered on such features as the total area available for use at the time of data collection and the total volume available for harvest at the time of data collection. These inventories were designed to provide a picture of what was available on the ground at that time. They were carried out and reported entirely in the context of the development at issue, i.e., they had an economic (or an accounting) base. Thus, the first unavoidable sign of overdevelopment was when one of these inventories undertaken to justify the newest step in development showed less resource than expected, even after the usual adjustments for lower utilization standards (Tweeddale 1974).

To discover why a conventional inventory showed less material than could be expected on the basis of the historical sequence requires that resource dynamics be examined. Not surprisingly, not much information is available on dynamics because the information gathering had concentrated on a static inventory of material that had immediate economic value. The first approximations of forest dynamics were therefore based on simple assumptions (Baskerville 1976, Hall 1978). The emphasis of studies of forest dynamics was on forecasting the availability of particular quantities and qualities of raw material in the future, rather than on what was actually there. A major difficulty was that the problem was perceived at the forest or regional scale, where data on dynamics were particularly poor. So a bridge had to be built from the relatively data-rich tree and stand scales to the regional forest scale. This exercise in problem definition is not simple and is resisted by a considerable amount of rationalization. One hears that "someone is always forecasting a timber famine and it never comes about, and this one won't either"; that "forecasting with models is silly because everyone knows that with computers it's garbage in garbage out." The realists of the world will state incessantly that "what counts is what is." And some people are certain that technology will permit even lower utilization standards or, indeed, the use of materials other than wood to produce paper. The point here is that there is significant resistance to the recognition of overdevelopment of the industry and the need for resource redevelopment because such recognition forces change in the established ways of using the resource for economic gain.

The need for redevelopment of the forest and the forest-based industries of New Brunswick eventually reached the social and political agendas, despite all these forms of resistance. In the end, even the most myopic recognized that the local industry was competing in world trade and that it was inefficient with respect to that market. The inefficiency in trade was traceable in large part to a high cost of raw material, which in turn was the result of the changed forest structure, which of course was the result of development. The gains in development in terms of quality of jobs and the local economy were, in the end, imperiled because of the inefficiency of the resource in the processing part of the system. Sawmills that could not adapt technologically to the smaller tree size closed. Major technological changes took place in pulp mills, and interest in maintaining certain pieces of physical plant associated with past development was reduced.

When awareness of nonsustainability finally dawned, it was simultaneously accepted that the economy could no longer be managed by mining the resource, so the resource must henceforth be husbanded. This recognition (or cognition) by the decisive players in industry and government was a relatively sudden event, occurring in an interval of about five years from 1975 to 1980. The turning point came when the decision makers ceased to argue about whether or not a problem existed in maintaining the flow of quality raw material. Once that occurred, action toward redevelopment followed rather quickly (Fellows 1980, Ker 1981).

Acceptance of a need for change came first to the decisive players in industry and government and not to the general public. The public did, indeed, voice an earlier need for change; however, their desires had a definite air of unreality, in that they demanded a continuation of all (or even more) of the economic benefits of development in full measure, while corrective action was to be taken at no cost. Tension developed because industry and government had inadvertently obscured the evidence of the problems of development by the choice of data collected on the resource. This incredible lack of public understanding of the historical linkages between the benefits and the problems persists, indeed has intensified, five years into the redevelopment program.

For the New Brunswick industries based on the forest resource, the program of redevelopment has involved several closely related activities. Once the industrial capacity clearly exceeded the ability of the forest to sustain raw material of the desired quality, the resource had to be reallocated to ensure even (or steady) resource use. The reallocation of access to the resource was not just in terms of areas of domain as had been prevalent in the economic development phases, but rather related to access to a particular piece of the productive structure of the forest. Allocation was to a share of the sustainable productivity of the resource, rather than to the standing inventory on some particular piece of ground at the moment of allocation (Hanusiak 1985).

Recognition of the need to allocate access to productivity required an entirely new approach to the acquisition of information on the productive state of the forest. New surveys of the forest were needed that sought to characterize the resource in terms of its dynamic structure, rather than in terms of a static storehouse of raw material. These new surveys required major expenditure in terms of a new form of aerial photography for the province, with special tests of methods of photointerpretation to discover the best ways to capture information on the stage of development for each stand. Methods for handling this geographic information had to be developed (Erdle and Jordan 1984). Not surprisingly, this task has proved to be complex, and the first approximation of data acquisition on forest dynamics is just a first step.

A major characteristic of the recognition of the need for redevelopment is the appearance of concern with forecasting future development on the regional forest scale. During the period of development, interest in the future rarely extended beyond the current-year harvest, and at best to a five-year harvest plan. Those facing the reality of redevelopment have suddenly acquired time horizons of 40 to 50 years. The need to forecast wood availability by amount, quality, location, and timing has resulted in the development of a large array of models that attempt to mimic dynamics at the stand and forest scales. These models were very simple at first, but are quickly developing as more information on dynamics becomes available, and as the necessity for forecasting becomes more clear. To manage a forest, explicit forecasts must be made of the availability of raw material in terms of quantity, quality, location, and time for a variety of patterns of intervention (such as harvesting, planting, and thinning). The forecasting tools were developed and accepted at a surprising rate. Approaches that were rejected as unnecessary, or unrealistic, five years ago are now embraced and ardently developed to improve their reliability.

The most traumatic element of redevelopment has been the need to actually design and implement management interventions. During the earlier period of development, much experimental work with silviculture was done, along with a certain amount of what might be termed the anecdotal practice of silviculture. All of this effort was characterized by an approach at the local or stand scale. The managers would examine a stand and, based only on what they saw at the local scale, determine the "best" silviculture action to be taken. Through this approach, some considerable experience had evolved with such tools as planting, precommercial thinning, and fertilization. With acceptance of the need for redevelopment, however, these local silviculture actions clearly had to be determined in the context of regional forest dynamics. Given that the harvest that can be taken is limited and that money available for silviculture also is limited, it is crucial that forestry actions be taken in the right places, in the right amount, and at the right time so that the development of the whole forest is regulated in the manner necessary to reach a goal of true resource development (or of economic redevelopment). Thus, the focus of intervention design has moved from the stand to the forest scale (Hall 1981). The question is no longer what can be done at this particular place but rather "what set of local actions taken in what places in the whole forest, and at what times, will cause the regional forest to transform and grow towards a particular chosen goal?" For a generation of managers, accustomed to making local stand decisions out of context of any regional forest picture, the necessity to place their actions in this regional context is proving difficult. A major problem here is that virtually all of the decision aids that have been developed in past decades are aimed at the stand or local scale, rather than at the larger scales. That is, economic decision-analysis methods assumed that, whenever management began, it would be carried out by a series of stand-by-stand local decisions. Major efforts are now underway to develop decision aids that place local actions in the regional context of forest dynamics.

Choosing a plan of management interventions for redevelopment is a complex matter. To be realistic, the plan must recognize that implementation of redevelopment will be local in nature (just as all of the actions of development were local in nature), but that these local interventions must be consistent with a regional pattern of resource development (Hall 1981). Management planning becomes an orchestration of local events to achieve a regional goal—what will be done, to what extent it will be done, when, and where—in order that a regional pattern of development, over time, is achieved. Moreover, management must address the real issues of who pays for this management effort and who carries it out.

Making all this happen on the ground is crucial. Implementing the plan as it is drawn up and providing a regular audit of performance of the forest are essential steps. This problem is unique to the stage of redevelopment because it was not necessary during development to worry about matching management platitudes with what was actually happening on the ground. During redevelopment, however, it is essential, for instance, that the actual harvest be taken in the same manner as used in the forecasts for management design. This need in turn requires a high degree of geographic control (Erdle and Jordan 1984). If, in the actual on-the-ground implementation of the harvest schedule, the "oldest first" rule is not followed and any younger stands are harvested because of local economic advantage, then some older stands escape harvest and will decay and become nonavailable for harvest. The net effect of this deviation of the real harvest schedule from the planned schedule is a reduction in the actual sustainable harvest. That is, in management, and particularly in management for redevelopment, the way things are done on the ground must be the same as the way things were done in the calculations determining sustainability. If the on-the-ground rules as determined in the plan cannot be implemented, then the plan must be changed to show an appropriately lower, sustainable rate of harvest. This requirement for making reality match the plans is perhaps the major source of tension in redevelopment (Hanusiak 1985).

The Fisheries of the Great Lakes

The setting and a historical sketch—The Great Lakes lie at the southern edge of the ancient Laurentian Shield where they straddle the Canada-US, border (fig. 1). Lake Superior is the largest and deepest lake, farthest upstream, and apparently created by tectonic events. The other four lakes were formed, or at least deepened and enlarged, by the continental glaciation of geologically recent times. The current ecological reality of the Great Lakes Basin is the result of some 10 millennia of the natural processes of postglacial succession and some two centuries of the effects of people of Western cultures.

Exploitive human uses, direct but indirect, have intensified at something like an exponential rate until about a decade ago; today, the overall effect may no longer be intensifying, but it remains, on balance, high. The Great Lakes are downwind of the industrialized Ohio Valley, from which airborne pollutants are often carried long distances. In contrast to the size of the area from which pollutants are transported through the atmosphere into the Great Lakes, the watershed of the Basin is small compared to the surface of the water, with no large rivers flowing into these lakes from the surrounding landscapes; hence the lakes are not rapidly flushed. Many of the small rivers and nearshore areas of the lakes are not as severely degraded as they were two decades ago. (The Cuyahoga River flowing into Lake Erie is no longer a fire hazard!)

Over 35 million people now dwell in the Basin. Most live in large urban concentrations with imperfect sewerage and sewage treatment systems, though most are less imperfect than they were a decade ago. Many of the residents work in industries that pollute because of rather obsolescent capital stock erected at a time of great interest in the nonrenewable resources of the Basin (iron, coal, and limestone) and of little concern for those resources that were potentially renewable at sustained rates. Major uses (including abuses) of the Great Lakes have been separated into about 20 classes, of which fishing is but one (Francis et al.1979).

By about 1930, the people of the dozen or so largest cities in the Great Lakes Basin had turned their backs to the lake shores and coastal waters that had become degraded; apparently the degradation was taken to be an unfortunate but necessary sacrifice to industrial-economic progress. Cities that thrived had dirty air, foul waters, and some urban slums. Today, however, the situation has changed, and people and institutions in the Great Lakes region are seriously searching for a new basis for the regional economy. In fact, the waters of the Great Lakes, and in particular the coastal waters, are now seen as a great natural resource, at least if their quality can be improved and then maintained. Somehow, an ecologically rehabilitated aquatic ecosystem is expected to contribute directly and also catalytically to the postindustrial redevelopment of the region (Thurow et al.1984). Rehabilitation of the fish, together with restoration of high water quality, are beginning to be linked by the public to the goal of sustainable redevelopment of the whole Basin's economy. It is coming to be accepted that the state of the fish community is a valid integrative indicator of ecosystem quality (Ryder and Edwards 1984) and—somewhat more distantly—of the regional quality of life for humans. Some even suggest that the Basin provides the single best indicator of the state of biospheric husbandry as practiced in industrialized North America. The lake trout in the Great Lakes indicate what the white pine indicates in New Brunswick.

The historical sequence related to highgrading in forestry has a close counterpart in fisheries of the Great Lakes. In fisheries, the process is sometimes termed "fishing-up," whether among size of quality classes within a stock or species (Ricker 1961), among locales within an ecosystem or region (Regier and Loftus 1972), or among species within an entire fish association (Regier 1973, 1979). By about 1940, the most preferred species in the Great Lakes were exploited by the fisheries to the point of a risk of overexploitation, if not, in fact, beyond the point of overexploitation (see figs. 8 and 9).

Throughout the process of fishing-up (or progressive highgrading), the enterprising fishers also progressively added value to their products through salting, refrigeration, freezing, filleting, smoking, precooking, and so on. An approximate parallel to the plywood and chipboard products may be canned fish and (as yet experimental) fish sausages. Something comparable to the pulp and paper stage of the lumbering industry has not yet emerged in the Great Lakes, but it has appeared elsewhere with new Japanese technology to produce surimi products (such as artificial scallops and crab legs) from the macerated flesh of low-valued finfish species. Serious plans have been drafted to bring this surimi technology into the Great Lakes fisheries.

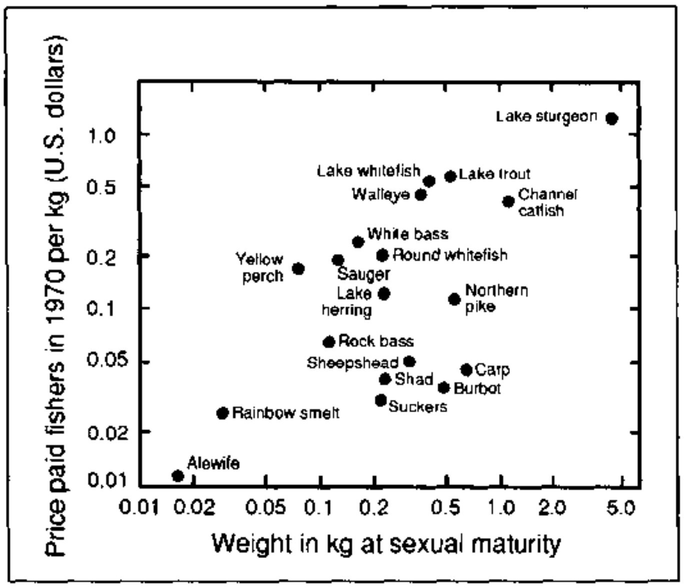

Figure 8—Value to fishers (1970 U.S. prices) of a kilogram of fish whole weight as a function of the average size of a species at sexual maturation (log scale) (Regier 1973).

Before 1940-55, the fish association of the Great Lakes was strongly and adversely affected ecologically by four stresses caused by people: fishing, blocking of streams by dams, loading of putrescible organic waters into streams and estuaries, and physical destruction of wetlands. During 1940-55, these four stresses were joined, and often superseded in local intensity, by four additional stresses: cultural eutrophication, industrial pollution, pesticides and other hazardous chemicals, and expansion of low-valued or harmful exotic fish species, such as the alewife and the sea lamprey. These latter four stresses had appeared locally long before 1940, but it was only then that their effects came to be regionally pervasive in many parts of the lakes. Other stresses of various kinds were also acting (Francis etal. 1979) and sometimes intensifying, but they must be set aside as miscellaneous in this short account.

The year 1955 may be taken as the beginning of growing public cognition that the Great Lakes, as parts of a system, were severely debased. In general, the lower the lake in the drainage system, the more thoroughly it was debased. The total binational cost of all the relevant studies and corrective efforts between 1955 and 1985 is unaccounted, but might well exceed $10 billion (1985 U.S. dollars). Most of the scientific efforts to understand this problem and almost all practical efforts to do something about it before 1985 were focused on locales and have attempted to deal with the problem one factor (even one chemical) or one species at a time.

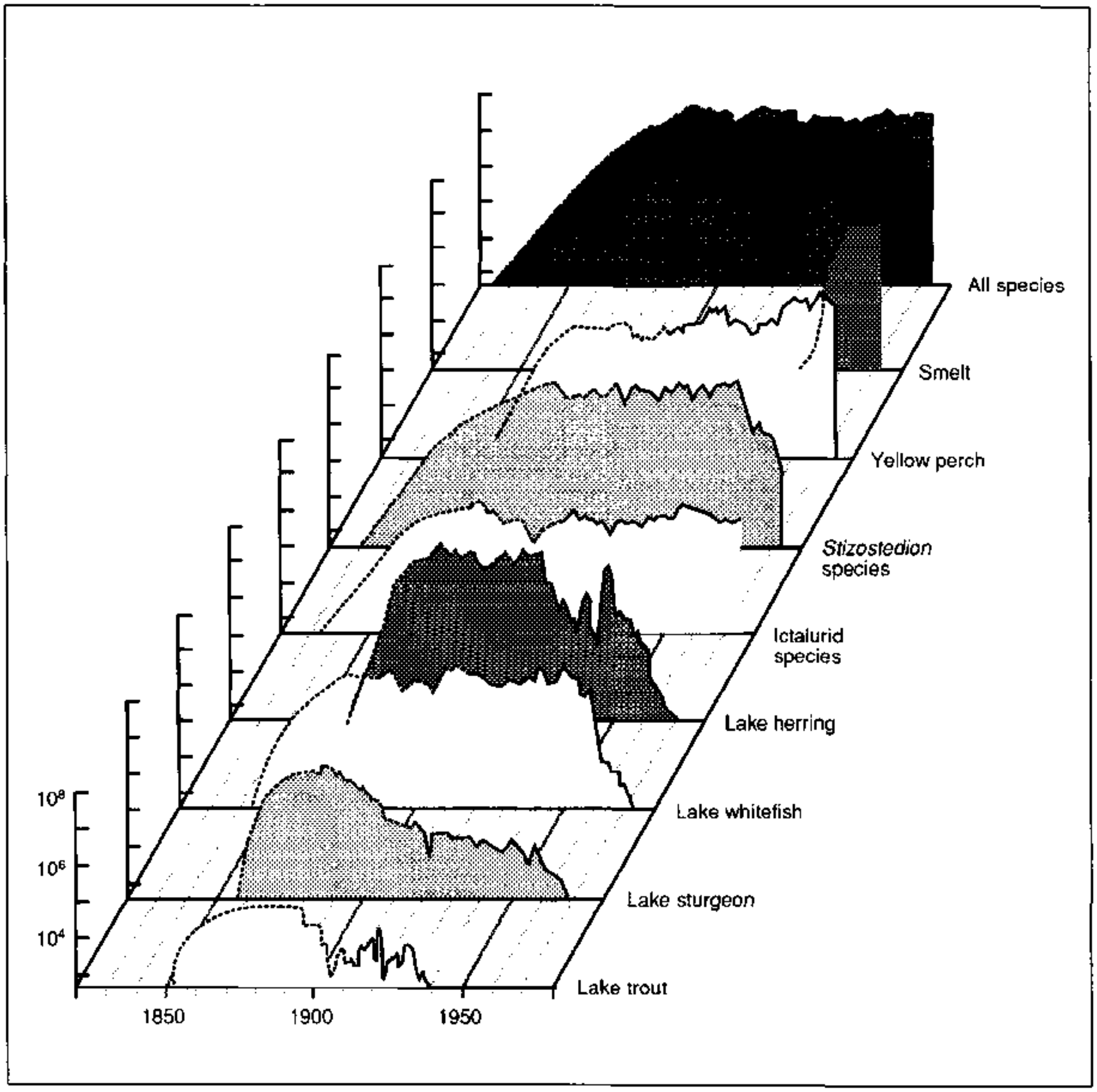

Figure 9—Lake Erie fish landings, by selected taxa, in kilograms.

At about this point in our historical sketch, convention would dictate that an account be given of the structures and processes of the governance of these binational Great Lakes, with a strong emphasis on the role of the International Joint Commission (Willoughby 1979). For a study of sustainable redevelopment of the biosphere, we do need eventually to deal in depth with the governance institutions. Suffice it here to say that no government agency—binational, federal, provincial, or state—has asserted or been given a mandate for leadership with respect to an integrated program of sustainable redevelopment that is now so necessary. No government agency has sufficient responsibility or authority to act locally and to think regionally in an integrated, ecosystemic way. Clearly the "think regionally" part of the aphorism is made more difficult to achieve in this multicity, multijurisdiction, binational situation; however, intergovernmental and broader networks are evolving that are beginning to serve this function. Within the (as yet) piecemeal efforts to correct the causes of the degradation of the Great Lakes are many detailed differences in the politics and practices of different jurisdictional, governmental, and intergovernmental entities. But these differences do not obscure the basic unity within the sequence of exploitive development of the two centuries of domination of the Great Lakes by Europeans and their descendants. Time lags may occur between jurisdictions, different priorities, internal inconsistencies, and so on, that can be very annoying, but the historical degradative trends and current corrective efforts are sufficiently similar that they can all be subsumed under the generalized concepts of exploitive development and sustainable redevelopment.

Exploitive development—We now examine some of the main ecological phenomena related to exploitive development of the Great Lakes, and thus also related to sustainable redevelopment. Francis et al. (1979) have sketched some of the main effects on the fish association (and on other highly valued, sensitive ecological subsystems) of the many stresses operating in the Great Lakes. This approach has been fine tuned to the very degraded Green Bay (Harris et al. 1982) and to the relatively well-conserved Long Point with its bays (Francis et al. 1985). The disheartening realization has emerged that most, if not all, of these stresses, acting singly or jointly and to excess, entrain an ecological syndrome of degradation or debasement (Rapport et al. 1985).

Some features of this syndrome, as it relates especially to fish, have been sketched as follows (Paloheimo and Regier 1982, Regier and Grima 1984):

- The major ecological stresses associated with human uses as conventionally practiced often act synergistically within the ecosystem so as to exacerbate each other's adverse ecological effects; they seldom act antagonistically so as to cancel out adverse effects.
- The stresses separately and jointly act to alter the fish association from one that is dominated by large fish, usually associated with the lake bottom and lake edge, to one characterized by small, short-lived, mid-water species. A similar change happens with respect to vegetation; firm-rooted aquatic plants originally nearshore are supplanted by dense suspensions of open-water (pelagic) plankton algae. Further, the association of relatively large benthic invertebrates on the bottom (such as mussels and crayfish) is supplanted by small burrowing insects and worms (such as midge larvae and sludge worms). Broadly similar changes occur in the flora and fauna of the wetlands and near-shore areas bordering these waters.
- With the above changes, an increased variability in abundance of particular species occurs from year to year, but especially in landings of different fish species by anglers and commercial fishers. Fluctuations are also more pronounced in the species associations of wetland, benthic, and pelagic areas.
- The shift from large organisms to small organisms is not accompanied by a major increase in the total standing biomass of living material, but it is accompanied by a reduction in the production of the most preferred species.
- In the offshore pelagic region, a new fish association—mostly of exotic species—may be created in which the small fish, such as alewife and smelt, may serve as a food resource to large predatory fish, such as salmon, which, however, must be maintained through the capital-intensive technology of fish hatcheries.
- Market and sport value per unit of biomass are generally much lower with small mid-water fish species than with large bottom species, and processing costs are higher. Similarly, the aesthetic value to recreationists of the rooted plants nearshore is higher than a turbid mixture of suspended algae and pollutants.
- The effect on fisheries, in the absence of the put, grow, and take stocking of hatchery-reared predators, is that nearshore, labor-intensive specialized fisheries (sport and commercial) tend to disappear, though highly mechanized, capital-intensive offshore enterprises may persist, if the combined stresses do not become excessive and if the fish are not so contaminated as to become a health threat for those who eat them. Yachts may quickly sail from polluted marinas through the foul coastal water to the less-offensive offshore waters. Beaches are posted as hazardous to health.
- The combined effect is one of debasement and destabilization of the system of the natural environment and its indigenous renewable resources with respect to the features of greatest value to people.

Rapport et al. (1981) have termed the above list a "general stress syndrome" and have inferred that such a syndrome may be observed in terrestrial as well as aquatic ecosystems that are subjected to the stresses typical of conventional exploitive development (Rapport et al. 1985). Indeed, we see analogs for each of the above symptoms in the New Brunswick forest example. Discovery of this syndrome has rendered obsolete any general policy of managing human uses of ecosystems as though they were ecologically independent. Recall the point made in the preceding section about forests: conventional development acted destructively on the underlying natural processes that had generated high-value resources. Some stress and consequent disturbance of the natural generative processes are inevitable when humans intervene, but the extreme, combined destructiveness of the various abuses related to exploitive development was a result of deeply misguided policies and practices, which may have made contemporary sense, but which often involved self-imposed ignorance. Sustainable redevelopment must seek to cooperate more closely with the natural processes that yield resources of high value.

Sustainable redevelopment: design and implementation—Attempts to arrest and reverse the degradation of parts of the Great Lakes ecosystem, including its fisheries, were begun over a century ago. Gross pollution with organic matter such as sawdust and offal was contained, in part. Destructive fishery practices were outlawed, such as dynamiting or setting nets across streams used for spawning. Fishways were made mandatory for dams, but the fishways were seldom effective. With the advent of steam and electrical power, many of the small dams across tributaries of the Great Lakes fell into disuse and were washed away. In large rivers, in this region and elsewhere, bigger and better dams were constructed, often without functional fishways.

Several factors were responsible for the escalation of the degradative practices—an escalation that remained uncontained until very recently. These factors, which must be reformed in a design for redevelopment, were:

- An unstated policy, shared binationally, that degradative abuses be addressed only after some particularly abused groups of the public raised a great clamor. Thus, time lags were common, seldom less than a decade, between the experts' and abused people's awareness of degradation and some beginnings of corrective action, almost always initiated slowly by the government. This problem was not as severe with the New Brunswick forests, perhaps because of the lower population density and the smaller number of nonconsumptive users. Also in New Brunswick, a more direct feedback imperiled the economic structure, which may have attracted the attention of business and bureaucracy sooner than in areas where the links are less direct, as with dirty water in the Great Lakes.
- Such corrective actions as were taken were designed so as not to impede exploitive development to a serious degree, as was also true in New Brunswick. Corrective actions were seldom fully effective, sometimes hardly effective at all, and sometimes they redirected the problem to other parts of the ecosystem.
- An unbroken tempo appeared in the advent of new user groups with direct and indirect demands on these ecosystems. The feasibility (or likelihood) that new users were likely to exacerbate the environmental impacts of existing users was generally ignored.
- The spatial and temporal scales of the degradative impact of various user groups tended to increase with technological advances related to those uses, but may have become progressively less apparent to the laypersons, even the most observant—such as with acid rain, atmospherically transported toxic contaminants, leaching from landfill sites, consumptive use of water, and so on. The related effects are not readily seen until researchers present generalizations and abstractions of regional impacts.
- Corrective action usually consisted of an attempt to reduce the extent and intensity of the abuse with little effort at mitigation or at rehabilitative intervention (ecosystem therapy) to foster recovery processes consistent with the natural healing processes. A conventional engineering approach tends to move a problem to a different place or time. It does not appreciate that biological systems have a memory or imprint of past actions—that just stopping an abuse does not necessarily lead to self-correction. Corrective intervention is often required.

The lag between public awareness of a serious problem and public perception of an improvement after corrective action is now about a quarter of a century. The aggregated rate of ecosystemic degradation in the Great Lakes may have peaked (or ecosystem quality may have "bottomed out") in the early 1980s—or it may not yet have done so. Problems with contaminants leaching from landfill sites, from acids and toxic materials transported atmospherically, and from consumptive use of water appear to be waxing, while those caused by acid rain, toxic fallouts, nutrient loading, and exploitive fishing are waning. Whether or not the aggregated rate has peaked, the evidence does indicate that the rate of degradation has been slowed.

The five policy factors sketched above appear to apply to both our cases of regional fishery and regional forestry development. As a policy, sustainable redevelopment must establish a framework that focuses the design of corrective actions on these factors. At the regional scale, focused discussion on how to correct them, as a systemic set, has been initiated only recently.

A mandate for a binational policy of sustainable redevelopment for the Great Lakes, with some management responsibility at the binational scale, may be inferred from a study of several binational agreements in the context of what we now know about the ecological effects of uses and their interrelations within the Great Lakes ecosystem. These agreements include:

- The Boundary Waters Treaty of 1909, served by the International Joint Commission (IJC).
- The Migratory Birds Convention (MBC) of 1917, served by an intergovernmental committee.
- The Great Lakes Fishery Convention (GLFC) of 1954, served by the Great Lakes Fishery Commission.
- The Great Lakes Water Quality Agreements of 1972 and 1978, overseen by the IJC.

Crucial gaps remained in 1985 that had not been sufficiently addressed by then:

- An agreement on long-range transport of atmospheric pollutants, with its acid rain, toxic fallout, and smog-related aerosols.
- An agreement on consumptive use, extra-Basin diversion of water, or both.
- An agreement with authority to take specified, local control actions in a regional control context, i.e., on levels and flows.

Human practices related to the following ecological features are being managed—in a weak sense of the word—under the four rather general agreements sketched above: water levels, water flows, water quality, and local air quality (IJC); fish quality and quantity, and the predaceous exotic lamprey (GLFC); and waterfowl, shorebirds, and, by implication, the wetlands (MBC). Within an ecosystem context, uses of most of these features obviously cannot be managed effectively in the absence of complementary management of some other features. For example, the interrelationships between water quality, fish quality and quantity, the sea lamprey, fish-eating shorebirds, and wetlands as nursery areas for fish and birds is well documented in the scientific literature. Those who have a responsibility for management must have the full perspective.

An ecosystem approach has been endorsed by the two national parties to these agreements, as well as by various other levels of government. With respect to water quality, the ecosystem approach has been endorsed formally at the regional or Basin scale in the 1978 Great Lakes Water Quality Agreement and explicitly, though less formally, at both the Basin and lake scales, as the policy of the Great Lakes Fishery Commission. This ecosystem approach is beginning to be interpreted in the sense of what we have termed Basin-wide sustainable redevelopment (Research Advisory Board and International Joint Commission 1978, International Joint Commission 1982, Lee et al. 1982). As yet, no specific codification of the meaning of the ecosystem approach has been accepted widely. Ecosystem understanding of sublake ecosystems is quite advanced (Harris et al.1982, Francis et al.1985) compared with that of lake ecosystems or of the entire Basin ecosystem. In the context of "think regionally, act locally," few people have yet learned to think regionally, probably because it requires that personal (economic) issues be subsumed in a larger community context. That is, we live in and see the local context, but the regional context must be some sort of abstraction that cannot be seen or felt, but can only be comprehended.

Public and political commitment, such as it is, to reverse the degradation of the Great Lakes has come at a time of growing awareness that major parts of the old industrial base of the Great Lakes region will likely wane in absolute terms. Examples are the steel and automobile industries and related waterborne transportation services. Urban growth has slackened and some local jurisdictions have experienced net reductions in human population. Concern is great that the region not be relegated to a hinterland of the American Sun Belt (disparagingly called the Parched Belt) to which some of the seeming abundance of fresh water in the Great Lakes might be diverted. How a thriving regional modern economy might receive major benefits from the sustainable redevelopment of the Great Lakes Basin ecosystem is not clear, though many opinion leaders believe that the Great Lakes themselves are the key to such redevelopment. Obviously, the choice of indicators of redevelopment is crucial. "Think regionally, act locally" does not come easily with respect to a Basin ecosystem that is fractured into many jurisdictions and subject to many incompatible uses. Somehow the people of the Basin must together choose a future, and make a long-term commitment to its realization, rather than just passively wait for something better to come along.

Attempts to achieve sustainable redevelopment of the fishery depend on the progress of reform with the fishery and also on rehabilitation of the habitat of the fish, the environment. In a properly managed fishery in a properly managed freshwater ecosystem (of the Great Lakes type), the fish association is dominated by native, self-reproducing, highly valued, bottom-oriented (benthic) species that achieve large size and old age in the natural state. Recall that, by 1955, the fish association was well on its way to an inversion, toward dominance by exotic, low-valued, mid-water (pelagic) species that remain small and die relatively young; by 1960, the inversion or debasement was almost complete. The main stresses responsible were excessive fishing of the preferred species (highgrading), invasion by the sea lamprey which prefers fish quite similar to those that people like, invasion or introduction of small pelagic fish that thrive in enriched waters, eutrophication through enrichment, pollution of spawning streams, and a miscellany of additional causes.

Corrective local measures began to show promise in the early 1960s. These local measures have generated local responses, but as yet only limited, mostly informal coordination has happened at the regional Basin scale. These measures include:

- Direct control of the sea lamprey through barriers and selective chemical lampricides, with the sterile male technique due for field testing.
- Reform of fishing practices to permit a recovery of preferred species; in some jurisdictions, commercial fishing was limited in favor of sport fishing, which exerts less intense fishing pressure on the valued species.
- Hatchery rearing and stocking of native species, such as the lake trout, in an attempt to reestablish self-reproducing stocks where they had been extinguished in recent decades.
- Hatchery rearing and stocking of non-native species on a put, grow, and take basis, especially salmonids of various species, to suppress the vast stocks of small pelagic species and to supply a highly valued sport fishery.
- Environmental programs for reducing the loadings of phosphates to reverse eutrophication and to foster oligotrophication, which favors the valued native species.
- Ecological rehabilitation of some streams that flow into the Great Lakes to provide productive spawning and nursery areas, especially for large, native and some non-native salmonids.
- Banning some persistent pesticides, such as DDT, which were washed into the lakes and transported and deposited onto the lakes by atmospheric processes, and then interfered with normal development of young fish and other creatures.

By 1984, all the lakes showed signs that the fish associations were beginning to revert to a state of dominance by large benthic species originally native to the lakes. How quickly or how far this process will go is largely a function of what people will do next with the Great Lakes Basin ecosystem, and particularly depends on how we orchestrate our more local endeavors within the Basin context.

The fact that these preferred native species are so dependent on a healthy aquatic ecosystem has stimulated interest in proposals to use some of them as "indicators of ecosystem quality" (Ryder and Edwards 1984). A deep oligotrophic ecosystem should support thriving stocks of lake trout, a shallower mesotrophic part of the system should support walleye and yellow perch, and a nearshore part of the system should support black bass and pike. Aquatic systems dominated by such species are likely to provide water of a quality suitable for domestic use after minimal treatment, to be productive of fish species that are highly valued by sport and commercial fishers, to be healthy for the contact recreation so important in heavily urbanized areas, to be attractive for recreational boating and nature study, and to be naturally self-regulatory to an important degree if all the uses are practiced in a manner that is well informed in the context of sustainable redevelopment. Sustainability must be defined according to type, intensity, and frequency of use—subject to ecosystemic maxims defined locally and regionally.

Sustainable Redevelopment of Regional Natural Resource Systems

Degradation and recovery in general—Innis (1938), Rea (1976), and others have exposed some far-reaching general parallels in the way various renewable resources were exploited in Canada and the United States during the past two centuries for the purpose of what is now termed economic development. Parallels can be traced in the histories of the exploitation of the New Brunswick forests and of the Great Lakes fisheries, though these parallels may not be as close as between New Brunswick fisheries in the Gulf of St. Lawrence and New Brunswick forests, or as between Great Lakes fisheries and Great Lakes forests (Flader 1983).

The breakdown of ecosystems, as ecosystems, under human influences and their recovery after relaxation or mitigation of those influences is attracting increasing attention (Holdgate and Woodman 1978, Francis et al. 1979, Cairns 1980, Barrett and Rosenburg 1981). With respect to ecosystem organization in a quite general sense, the closest biotic counterparts in ecosystems like the Great Lakes and the dominant species of trees in a natural forest like that of eastern Canada may be the dominant, large, relatively sedentary species of fish (Regier 1972). In the pristine forests of eastern Canada two centuries ago, as in the pristine Great Lakes, much of the total living biomass was contained within such dominant species. Elton's energy pyramid of trophic relations is sometimes incorrectly taken as indicative of biomass proportions in natural biotic associations of lakes, such as the Great Lakes. In natural lakes, the plant species, both the macrophytes and the phytoplankton, have a quick turnover, but some individuals of the large species of terminal consumers and predators survive for decades, such as lake trout and lake whitefish, and some up to perhaps a century, such as sturgeon and snapping turtles. These relative rates (and corresponding biomass proportions) are reversed in forests between, say, white pine and insectivorous birds. Note that the turnover rates of the economically most-valued components are quite slow in each case, and hence recovery after abuse stops will also be slow in each case.

Incidentally, in natural grasslands and wetlands the relative biomass of producers versus consumers plus predators may not be as strongly skewed as in forests or lakes. Grasslands and wetlands appear to be more at the mercy of climate and natural fire with "wipe out" events more frequent and less localized than in either forests or lakes. Neither the plants nor animals tend to grow very large or old in grasslands and wetlands. Large animal species of the forest tend to exploit grasslands and wetlands for forage, and large animal species of the lakes tend to use wetlands for spawning and nursery areas. Rapport et al. (1985) have shown that the terrestrial and aquatic degradation syndromes caused by exploitive developments of many kinds are, in some ways, similar ecologically. The degradation syndrome may be seen as a pathological reversal of the usual natural developmental, successional, and morphogenetic processes that have been characterized by von Bertalanffy (Davidson 1983) as follows:

> Bertalanffy's model of hierarchical order was furnished by him with four related concepts: As life ascends the ladder of complexity, there is progressive integration in which the parts become more dependent on the whole, and progressive differentiation, in which the parts become more specialized. In consequence the [system] exhibits a wider repertoire of [functional] behavior. But this is paid for by progressive mechanization, which is the limiting of the parts to a single function, and progressive centralization in which there emerge leading parts that dominate the behavior of the system.

The science of surprise and the practice of adaptive environmental management of C.S. Holling and his colleagues (Holling 1978, 1986; Regier 1985) may relate in the first instance to both the normal, natural morphogenetic sequence and the human-caused exploitive degradative sequences, in a general systems context. For example, forest resource degradation is a surprise because we were not collecting data on forest development and degradation—but if proper data had been gathered, such a surprise would not have occurred or would have been less serious. One of the implications of Holling's ideas is that ecological sequences have discontinuities that may involve emergent behavior in the natural morphogenetic sequence and, presumably, may involve complementary submergent behavior in the human-caused degradation sequence. Such concepts can be helpful in comprehending the general consequences of opportunistic exploitation and for designing rehabilitative husbandry in a policy of sustainable redevelopment.

Mobilization of public and political support for redevelopment is hindered by a variety of incorrect myths about natural processes and characteristics of ecosystems, such as the following:

- *Large species tend to be inefficient producers of resources and should be sacrificed in favor of smaller species with quicker turnover rates.* This approach ignores the self-regulatory roles of large species that favor other valued features of these ecosystems. It also plays down the difference in per-unit value, with economic and aesthetic values of some of the dominant species high in comparison to most of the small species. In any case, the relative productivity of harvestable smaller species in aggregate is not likely to achieve twice that of harvestable larger species, and the difference in per-unit net values are likely to be greater than twofold, in inverse proportion to the rate of production.

- *Natural succession of lakes involves eutrophication and thus the preferred species of fish that thrive in less fertile waters are passing phenomena anyway.* This assumption is basically incorrect in that internal ecosystemic processes in lakes are generally oligotrophic, but eutrophication is generally caused by external processes, such as atmospheric loading with volcanic ash or by human loading of nutrients into the lakes, which override the natural processes that regulate nutrient concentrations.

- *As forests age, their susceptibility to natural forest fires, blow downs, and insect pest outbreaks increases greatly.* A natural forest tends to be a rather intricate mosaic of somewhat different associations, all at somewhat different stages of succession, and consequently not at all at great risk from natural causes.

General features of sustainable redevelopment—Let us look again at the concept of sustainable redevelopment. One can argue that the pulp and paper industry has been sustained and expanded in New Brunswick, but such sustainability was achieved only by virtue of drastically reducing the standards for raw material. This change has driven up the cost of raw material because the smaller material is more costly to harvest and handle (fig. 10). To be meaningful, the word sustainability must be accompanied by definitions of quantity, quality, time, and location. Does the conventional development of a white pine industry for 50 years before it runs out of suitable resources constitute sustainability? Does the existence of pulp mills for 50 years constitute sustainability? Is development still considered sustainable when it results in depreciation of the resource? How is quality of the resource to be specified, in that the quality of raw material determines the quality of the associated industry?

Where the specifications for sustainability include quantity, quality, location, and time, one need expect relatively few resource problems with development. In the absence of such specifications, development inevitably wanders into trouble. Development in our society has meant quick and short-term economic benefit, with the higher the interest rate, the shorter the time horizon. Development

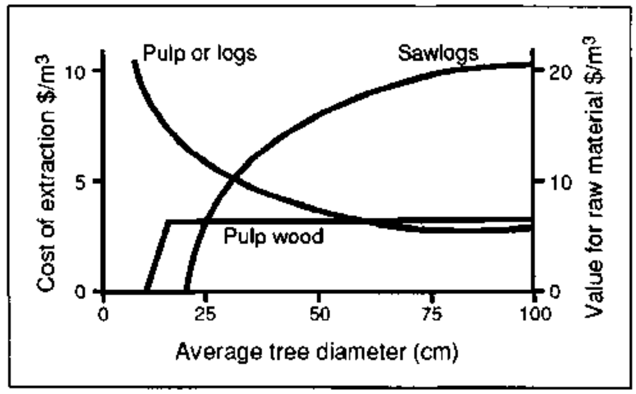

Figure 10—The relation of raw material value (pulpwood, sawlogs) and cost of logging (pulp or logs) to the average diameter of trees in a stand. Normally, market pressures limit pulpwood to smaller trees, and larger trees are processed for sawlogs. The cost of logging strongly depends on tree size but is little influenced by the intended raw material.

does not refer to the resource, all brave words at pulp mill or fish plant dedications to the contrary! Frequently, plans for sustainable development include all the highest platitudes with respect to resource management that one could hope to see, but it is rare to see any mechanism that forces implementation of these fine ideals.

Two characteristics of redevelopment need emphasis. The first is that the transition from development to redevelopment (or from exploitation to husbandry) necessarily produces substantial tension. Tension develops between industry (whether forestry or fishery), government, and the public, and the tension is heightened by a mutual lack of trust among the players. Industry believes that neither the government nor the public understand the intensity of the world-scale competition in which it is engaged. Government does not trust industry to maintain the necessary long-term horizon for a redevelopment program, and fears that the public may not understand that redevelopment will necessarily cost a temporary reduction in the flow of benefits from the resource. The public does not trust either industry or government, who are seen to be creators of the problem and hence unlikely candidates to design and execute a solution. None of these players has a very good understanding of the relation between local actions and regional goals, and consequently they each occasionally produce rather unrealistic action proposals. For example, the public has been so long taught that a tree should be planted for every one cut, or a fish stocked for each harvested, that the focus on local action is almost exclusive. Public outcry during the design of redevelopment has centered on local events, with the most naive notions about what the forest or lake system in the regional sense will do if their local actions are followed and with no sense of the orchestration of these local actions. A most counterproductive feature of this tension is the desire of some members of all parties to demonstrate that it is some other "they" who are to blame. In fact all three—industry, government, and the public—applauded and shared in the development that has caused the problem.

The second characteristic of redevelopment worth noting has to do with the geographic reality of planning the context of acting locally while thinking regionally (or globally). Many may talk about managing a resource and, indeed, about specific management actions, without ever specifying the actual location of these actions or even recognizing the need for such specification. Some may actually plan resource management without dealing with the regional context of local actions, although escaping the implications of context is impossible. That is, a plan that states that 5000 ha will be planted every year, 2000 ha precommercially thinned, and 3000 ha harvested, implies that someone knows precisely where each of these activity sums will be accumulated. (A similar statement applies to stocking lake trout in the Lakes.) When a management plan is implemented on the ground or in the water, however, explicit geographic reference in a regional context is inescapable and consequently few real redevelopers exist. Any plan requires implementing a series of local actions, which together cumulate to the desired regional effect. If the plan does not specify the geographic pattern of these local events, then the plan cannot be implemented. This statement is perhaps the greatest learning experience of the redevelopment phase.

So important is geographic control to implementing management that, in the historical absence of a technical capability for geographic control, exploitation was all that was possible. Certainly, if relating the parts of a geographically dispersed system in terms of both attributes and location is impossible, only the broadest form of management control can be done. Fortunately, such limitations are being rapidly erased by computerized mapping systems embodying relational data bases (Erdle and Jordan 1984). For the first time, these systems allow the planner not only to design a regional resource redevelopment strategy, but also to identify readily the geographic locations where particular tactical actions must be taken to accomplish the regional strategy. In systems where broad geographic extent adds to both the cost and complexity of resource exploitation and to the cost and complexity of resource management, the ability to analyze the same resource data at appropriate scales for strategic and tactical designs is a major technological breakthrough. Characteristically, the exploitation nterests have been as aggressive as management interests in implementing these expensive systems; this is true for the New Brunswick forestry example, but not for Great Lakes fisheries. In resources with many users and many managers with disparate responsibility, authority, or both, a common geographic data base is crucial for avoiding antagonistic strategies and permitting coherent management design.

Management has been much talked about in the past and, indeed, a certain amount about planning as well, but little of the discussion has come to grips with the fact that to make a plan happen on the ground and in the water, in the forest and lakes where it really counts, management plans must specify where the local events will take place to achieve a specified regional effect. What separates real management (or husbandry) from those highest platitudes of development is the specification of geographic control of actions in the sense of: do this, at this time, to cause this to happen at this place in the future, so that the whole forest or lake ecosystem will develop along this desired pattern. Management, then, is acting locally while thinking regionally.

Local and regional decision making—In North America, the nature of rights to the direct use of a renewable resource and to the indirect use of the habitat that generates the renewable resource is very complex (Regier and Grima 1984, 1985). The heuristic schema in figure 11 may aid understanding of rights from the perspective of how these rights are exercised by the putative owners of them, and of how society administers the allocation and supervises the exercise of the rights.

A right to determine the use of a designated part of a renewable resource, its habitat, or both may be held exclusively by designated individuals or by duly constituted groups of individuals, or may be shared nonexclusively with others. From a complementary but orthogonal perspective, such rights may be transferred or exchanged between individuals or groups largely at their own initiative, or they may not be transferable (Dales 1975).

Eight different combinations of these two criteria are shown (fig. 11). The four outer corners are rather sharply defined, hard or formal manifestations of the four possible combinations, and the four inner corners

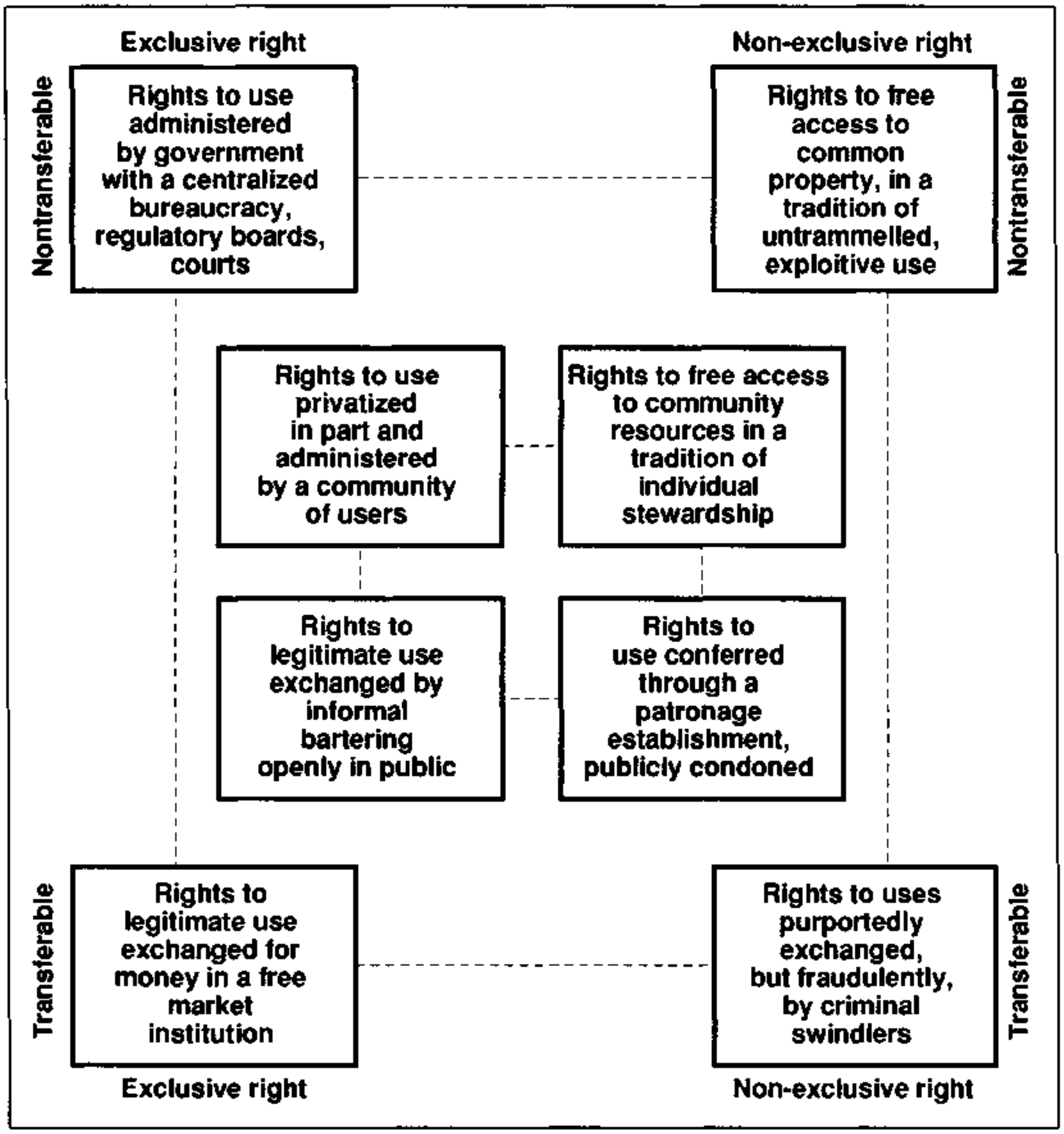

Figure 11—A perspective, expanded from a scheme by Dales (1975), on the variety of ways in which rights to the use of fish and similar resources are managed in North American Society. In the four inside characterizations, the exclusivity and transferablilty of user rights are satisfied in a practical manner. User rights in these four inside types are less sharply defined than those in the four corners. The schema may be viewed to have a soft core with a more sharply defined hard shell or edge.

are less clearly defined, soft or informal counterparts of the outer set. Note that exercise of an illegitimate right has been included, in part to complete the schema, but also to take note of the fact that such illegal actions are not uncommon and do affect the exercise, by others, of their legitimate rights.

Regier and Grima (1985) have suggested that the set of four hard elements, where they are condoned in practice by society, may become organized into a kind of competitively interdependent complex. In contrast, the soft elements may develop into a more mutual interdependent complex. Where a particular complex is dominant, the interdependent process may link with the relevant social mores to effect a kind of positive feed-back reinforcement of the dominance—for example, free enterprise and exploitation.

In some very general way, the interdependent hard set may be used by the forces that dominate conventional exploitive development, especially as imposed from a metropolis onto a hinterland. This use may happen with

Table 1—Institutional or policy mechanisms for managing aquatic ecosystems and for allocating the use of fish and their habitats.[a]

Mechanism	Instrument of control	Purpose orobserved consequences
Prohibition	Exclusion of sport fish from commercial harvests.	Improve recreational opportunities for anglers.
	Specification of zero discharge of some toxics orcontaminants.	Reduce exposure of biota and humans to poisons.
Regulation	Specification of low phosphorus concentrations in sewage effluents.	Control eutrophication which, if intense, degrades the aquatic ecosystem.
	Specification of gear and area, in fishing.	Reduce fishing intensity to prevent overfishing.
Direct government intervention	Control of non-native sea lamprey by lampricide. dams, etc.	Foster recovery of lake trout and other preferred species to benefit fishers.
	Development of islands and headlands with fill and dredge spoils.	Provide recreational facilities and spawning areas to benefit anglers, boaters, etc.
Grants and tax incentives	Subsidy to industry for antipollution equipment.	Lower pollution rates and distribute costs more widely.
	Subsidy to commercial fishers to harvest relatively undesirable species.	Reduce competition from undesirable species to benefit preferred species and their users.
Buy-back programs	Government purchase and retirement of excess harvesting capacity.	Reduce excess fishing capacity and compensate owners of the excess capacity.
Civil law	Losers enabled to sue despoilers in civil court.	Preserve ecosystem amenities for broader public; recompense losers.
Insurance	Compulsory third-party insurance for claims of damage.	Reduce pollution loadings because insurance premiums are scaled to loading.
Effluent charges	Charge for waste disposal, either direct cost of treatment or indirect cost of impacts on ecosystem.	Reduce pollution, allocate resources to high-value, profitable uses, or both.
License fees	Tax or charge on harvester, scaled to amount of use.	Foster efficient use of resource by discouraging overcapitalization, recovering fair return for the owners (public) of the resource.
Demand management	Rates involve marginal cost pricing, peak responsibility pricing, orboth.	Improve overall efficiency of use and foster conservation.
Transferable development rights in land-use planning	Limited rights to develop one area exchanged for broader rights to develop another.	Direct the development to areas preferred by government.
Specific property rights, as with transferable individual quotas	Purchase of pollution loading rights to predetermined loadings.	Limit pollution and foster efficient use of resources.
	Harvest rights to explicit quantities to be purchased.	Limit effective fishing effort and allocate resources to high-value uses, profitable uses, orboth.

[a] Items at the top are largely administrative, and those at the bottom have a prominent role for the market system (examples relate to the Great Lakes of North America).

private capitalism where the free market is a dominant element within the set, or with state capitalism where the administrative element (linked to the international market) is dominant.

Locally, in an established, healthy human community, much of the exercise of rights occurs within the general framework of the soft, informal set. This use is seen most clearly with respect to sharing within a family, whether nuclear or extended. This more informal approach to the identification and practice of rights may be severely distorted by cultural invasion of the more formal approaches associated with conventional development. Also, some of the small-scale, less informal rights enjoyed by a community may be vitiated by the exercise of the exploitive rights of the developers.

North American societies have had great difficulty in dealing with the injustices and inequities visited on local communities by external developers. The wrongs have often been rationalized by a rather simplistic utilitarian ethic of the greatest good for the greatest number, with some abstract logic about the desirability of Pareto-optimality, if only it could be implemented. We think of what has been done at federal and provincial scales with the objective of maximizing the net value added, with less consideration of how the resulting benefits are distributed among people. Is value added a good measure of progress?

Currently, a swing to neoconservatism has brought with it a preference for the market as an allocator of rights to use and has brought antipathy for the administrative function which had come to be dominant. Such a change in preferences may be interpreted as a shift in the center of gravity of the whole interactive complex, now involving both the hard and soft sets (fig. 11). The shift is toward the lower left of the figure and away from the upper left and also away from the central soft set. Green parties, as yet minuscule in North America, would presumably favor some dominance by the soft set over the hard set.

Compromise intergrades of various kinds have been developed within the spectrum of strictly administrative and strictly market methods (left side, fig. 11; see table 1, page 42). Some of these compromises could also be adapted to serve as intergrades between the hard and soft sets. To be most effective in redevelopment, the selection of mechanisms must be chosen and designed to use a constructive feedback loop to make developers want to manage because it is in their interests. All else may be futile.

In the context of rehabilitative husbandry for sustainable redevelopment of regional ecosystems, the complex regime of rights should be organized so that a well-functioning interdependent soft set of local allocative methods should not be overridden destructively by an interdependent hard set of allocative methods serving primarily those interests defined at a regional scale.

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Historical Interdependence Between Ecology, Production, and Management in the California Fisheries

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The organizing topic of this set of papers was "the nature of our obligation as fishery professionals to present and future generations." Entailed in that organizing topic, so the symposium's organizers informed the participants, were three subsidiary questions. Those questions were, first, what is it that fishery managers are trying to sustain and why? Second, what social, political, or scientific problems undermine sustainable fisheries management? Finally, how might fishery managers undertake the intensive management of commercial resources without irreversibly altering the ecosystems upon which these and other resources depend? This article is an effort to address those questions from the perspective of the historical record of fisheries management in California, since it began to be actively concerned with the health of its fishery resources in the late nineteenth century (McEvoy 1986, 1988).

Fisheries management is an object lesson in John Muir's aphorism about Nature, to the effect that once one begins pulling at any particular aspect of the natural world, one inevitably finds it hitched to everything else in the universe (Teale 1973). What stands out from the history of the fisheries in this one jurisdiction are, first, the truth of Muirs notion that everything is connected to everything else and, second, how richly textured that truth is. That history suggests short answers to each of the three questions the conveners of this symposium put forward, in reverse order. How do we manage commercial resources without altering the ecosystems in which they are embedded? The answer to this one is easy: it's not possible. What social, political, or scientific problems undermine sustainable management? The answer to this one is easy, too: all of them. The first question—What is it that we're trying to sustain, exactly?—is the really interesting one. Moreover, the way in which one approaches the second and third questions depends a lot on how one answers the first one.

Many of our problems in sustaining fisheries historically have stemmed from the fact that managers have traditionally understood their task as one of sustaining a flow of wealth from something they identify as a "resource" into something they identify as "the market," both of those things conceived of as distinct from one another and each from their environments. The history of California fisheries management makes clear that, as a matter of fact, everything is connected to everything else and that people have problems when they try to treat things as if they were not.

What a fishery is, descriptively, and what management ought to try to sustain, prescriptively, is an interaction between three variables: an ecosystem, a group of people working, and the system of social control within which the work takes place. Each of the three variables has a good bit of its own independent dynamism, but each varies continually in response to changes in the other two. So it is not possible, in the nature of the case, to manage a resource as if it could be described and manipulated at arms' length. The best that fisheries managers can do is to monitor and adjust the interaction between a volatile ecology, a creative economy, and society's understanding and control as they go along.

Ecology

The ongoing history of fisheries management is best understood as an ecological one, consisting of a tripartite system of ecology, production, and management as it has moved through time. In California, the data for such a history are as variegated as the state's fisheries are themselves.

There are, first, a lot of useful historical data on California ecology, both on land and offshore. Army and Weather Service records of temperature and precipitation date back to the 1840s (McAdie 1903); we know from these records, for example, that the period between 1880 and 1920 tended to be cooler than the periods before and after. We also know that the decades between 1910 and 1940 were significantly drier than average. We know, finally, that significant climatic anomalies, probably associated with the El Nino-Southern Oscillation occurred in the mid-1950s, in the early 1920s, in the early 1880s, and the mid-1860s. All of these anomalies were associated with serious crises in the fishing industry, in response to which industry pressed for some political solution (Hubbs 1948, Radovich 1961, Cane 1983).

We also have an interesting set of geological data developed by the Scripps Institution from fish scales deposited in anaerobic sediment in the Santa Barbara Channel (Soutarand Isaacs 1974). These sediments are annulated, like tree rings, because winter sediment from the coast is darker and thicker than summer sediment; what the people at Scripps did was to take cores out of the sediment, date the layers, count the number of scales from different kinds of fish in each layer, and calibrate those measurements to modern estimates of those stocks' populations. The end result of all that work is a census of the major pelagic schooling species in the system (sardine anchovy, and mackerel) that goes back some two millennia (Smith 1978). We know from these data that the aggregate biomass of these schooling fishes has varied widely and continuously: it was extremely high in the 1830s, and again at the turn of the twentieth century, when the major industrial fisheries of this century (for salmon, sardine, and tuna) were first developed. We also know that since the sardine fishery collapsed in the late 1940s, the aggregate population of such fishes has remained far below any numbers in the geological record.

In this record, further, is an interesting relation between populations of sardine and anchovy. These two species are ecologically very similar, except that the anchovy has a shorter life span and breeds at a higher rate than the sardine does. What this knowledge does for us is to provide an index of the relative volatility of conditions in the system: highly unsettled conditions favor a species like the anchovy that turns its population over more rapidly; more stable conditions tend to favor the sardine (Smith 1978, Smith and Lasker 1978). We thus know that the system was both highly stable and productive in the 1860s, the 1890s, and the 1930s. The first period was when the sardine fishery was in its heyday. The system was in disequilibrium in the 1880s, when government fishery management began in California, during the World War I decade, and during the late 1940s and early 1950s, when the sardine fishery collapsed. On the whole, the California Current system is extremely volatile and all of the fisheries in them are vulnerable to random environmental shock. In sum, clearly a great deal of change takes place in the system, some of it quite drastic, whether people are working it or not. People who develop expectations about a fishery's productivity in good times may be caught by surprise a few years down the road.

Contemporary observations provide a wealth of more traditional historical data. We know, for example, that massive die-offs of sardine occurred off the southern end of Baja California in 1602 and off Monterey during the last week of May 1858, the first because the Spanish explorer Vizcaino noted it in his diary (Wagner 1928), and the second because the Monterey newspaper reported that a lot of Indians had come from inland to gather the fish for drying. We know that when Richard Henry Dana visited Santa Barbara in the 1830s, little or no kelp grew along that stretch of coast (Dana 1841), but in 1888 the kelp was so thick that coastal steamers had to have channels cut for them before they could come into port (USFC 1888). This last item tells us a lot about the system that we can correlate with the histories of the sea otter trade, the Chinese abalone fishery, and the near-shore market fisheries whose staples were yellowtail, barracuda, sea bass, and other kelp-living species (McEvoy 1986).

Finally, more-or-less systematic observations were taken by scientists, most of them on government payrolls, from time to time beginning in the 1860s. In all, direct observations by scientists and lay people provide good evidence as to what kinds of fisheries were prospering at what times, and which ones were doing poorly. It is thus possible, given current knowledge about the dynamics of the California Current system, to compare what modern science suggests was really going on in the system with what people at the time thought was going on and what they did about it. Perhaps not surprisingly, correlation between what people thought was happening to them at the time and what the data suggest was really happening is usually rare.

Production

All of these measurements tell us something about the ecology leg of the tripartite system. The second leg is that of production. The most striking characteristic of the industry's economic history is the familiar, cyclical pattern of boom-and-bust: new resources are discovered or come within reach of developing technology, harvests grow exponentially for a while, they level off, and the fishery collapses. The story, told in a single iteration, is unremarkable. What is remarkable about it is the innumerable quantity of its historical iterations and the seeming inability of people to do anything to prevent it.

One interesting aspect of this cycle as it has played out in California, however, has to do with the nature of economic development in the fisheries, both extensive (in the sense of geographic expansion) and intensive (in the sense of technological development). That is, that more or less coherent agglomerations of capital and labor tend to persist through the industry's history, shifting to new stocks or moving to new waters for new supplies of old stocks or changing their techniques in the service of either strategy when they deplete their old ones. One very interesting example of this phenomenon concerns the Sacramento River salmon fishery of the late nineteenth century.

The Sacramento River salmon fishery was established in the late 1860s by a couple of men from coastal Maine; these people were refugees from a salmon fishery that their families had worked since before the American Revolution but had since begun to decline under the impact of agriculture, industry, and other competing uses of water (Dodds 1959, Merchant 1989). Once established on the Sacramento, salmon fishing continued sporadically until the late 1870s, when the climate suddenly changed from a hot and dry "continental" regime to a cool and wet "marine" pattern. Suddenly, the runs of salmon in the system were unbelievable. At its peak, the fishery probably took 10 million pounds of chinook salmon out of the Sacramento River each year between 1879 and 1883. The runs were so heavy between September 15 and 17, 1880, that fishers at Sacramento simply threw 9,000 dead chinooks back into the river because no one would buy them. The boom phase of this fishery lasted exactly four years, or one modal chinook life span.

As the industry collapsed, most of its capital and labor moved northward, more or less bodily, first to the Columbia River, then to Puget Sound, and then to Alaska, depleting each fishery in turn. The industry behaved a little like a group of slash-and-bum farmers, except that enough people stayed behind at each place, making their average cost and no more, as the economics of the "tragedy of the commons" would predict, to make sure that the stocks got no chance to recover (Crutchfield and Pontecorvo 1969).

One California salmon processor moved from Sacramento to Monterey at the turn of the century and did two things: he outfitted a few motorized boats and began trolling offshore for salmon, which boosted the harvest but intensified the pressure on the Sacramento stocks; and he modified his cannery and a few of his boats and began fishing sardine. The sardine industry spread north along the coast to British Columbia, boomed during the twenties and thirties, and collapsed after 1945. In the early fifties, the sardine industry moved bodily, canneries and boats and even a few scientists, to Peru (Paulik 1971, Clark 1977).

The economic history of this part of the California fishing industry is thus one of a more or less coherent aggregation of labor, capital, and technology that endured nearly two centuries, from the 1770s to the 1970s. The industry had a kind of malignant ecological unity as it moved through two centuries and into three oceans. The same kind of story can also be told about whales and tuna (McEvoy 1986). The point is about the nature of technological and economic change in the fishing industry that comes to light only when one looks at it from an ecological and historical perspective.

Another interesting thing about fisheries in general and those in California in particular is the remarkably high degree of informal order under which they operate. Until about World War I in California, the fishing business as a whole consisted of a handful of disaggregated sectors, each made up of a different ethnic group fishing target species with which they had been familiar in their home countries. Chinese fished squid and abalone, New Englanders fished salmon, Italians fished nearshore market varieties, Portuguese hunted whales, and so on. Given the relative weakness of the state's fishery management apparatus before World War I, each of these disaggregated fisheries operated under its own law, more or less independently of the others and certainly from the state. The one Indian group that survived into the twentieth century more or less intact, those people who fished salmon in the Klamath River, likewise retained a great deal of power to order its harvest in its own, traditional ways.

These regimes could be quite vigorous. In the words of the San Francisco Chronicle in 1907,

> if anyone imagines that it is possible for a Chinese or member of any other nationality than an Italian to catch crabs in this bay for the market, let him try it. If any Italian thinks it is possible to catch crabs for the market without joining the Association, let him try it.

"Everything is governed by laws which the fishermen have made for themselves," reported David Starr Jordan some years earlier (Goode 1887).

Would-be competitors of these ethnically proprietary fisheries certainly seldom saw anything of substance in these arrangements except monopoly and piracy. Modern economists usually pay little attention to them either, as do law enforcement officials except when, as in Indian treaty fisheries, the courts force them to. The record suggests, however, that these tight little ethnic or tribal associations served an ecological function by linking the allocation of access to the resources to the long-term welfare of the group, and that their management record, historically speaking, in many cases looks at least as good and sometimes a lot better than that of the bureaucratic, scientific agencies that superseded them.

Similar groups that exist today, among the Cree Indians of James Bay, Canada, for example, or among lobster fishers in parts of Maine, likewise close off access to their fisheries, maintain a similarly high degree of order in their harvest, and tend to generate more net social income on a more sustainable basis than neighboring groups not so highly organized (Acheson 1975, Berkes 1977, McGoodwin 1990). In California, the very cohesiveness of these groups and the relative prosperity that they derived from that cohesiveness incited the envy of less organized competitors, who called on the political machinery of the state to destroy them, thus exposing those fisheries to the market failures that make up tragedies of the commons. The point here is a relatively conservative one, that a systematic, ecological, mutually reinforcing relation exists between the social and cultural organization of harvesting groups and the ecology of their target stocks.

Thus, a reciprocal, interactive relation exists between the ecological processes that determine a stock's productivity and the social and cultural processes that make fishers behave in the ways they do—that is, between the ecological and productive parts of my tripartite model of the fisheries. For a long time, of course, people thought that no such interactive relation existed; that is, that nature was essentially a passive store of resources from which harvesters could always take more and it would grow back. We know better than that now, although the idea persists, frequently hidden deep in the assumptions we make about what fisheries management is all about. Nowadays, the notion manifests itself whenever people act as if nature were resilient enough to take whatever burdens they can put on it, that some technical way of making nature produce more than it seems willing to will always be found, or that what all fishers want, when they resist outside intervention into their affairs, is to get more for themselves, beggar their neighbors.

Management

The reciprocal relations between the ecology of resources and the economic use of the resources is relatively easy to grasp. Fishers go where nature makes resources available to them; nature, in turn, changes its character whenever human use has an appreciable impact on it. Less intuitive is the reciprocal interrelations between management and both industry and ecology. Management, including both lawmaking and the scientific research that (at least ostensibly) informs it, clearly has some impact on the structure of the fishing industry and consequently, as the industry works in a responsible environment, on the ecology of the resources. At the same time, however, management is itself a product of the historical interaction between production and ecology, between fishers and fished.

Frequently, lurking deep within our assumptions about fisheries management is an assumption not unlike the one that postulates a sharp, hermetic distinction between ecology and production. Here, fishery managers frequently assume that the regulatory process goes on in isolation from the interaction between nature and production that it is supposed to monitor and regulate. This assumption about the management process, in turn, has two aspects to it. One facet of the assumption is the idea that lawmaking goes on in isolation, unaffected by the struggle for resources in the marketplace. The other aspect is the common assumption that the scientific information on the basis of which lawmakers regulate the fisheries comes to them as objective truth, free of political charge either in its generation or in the manner in which lawmakers put it to use. Both of these preliminary assumptions are wrong; both science and law are inextricably knit into the systematic interaction between ecology, production, and regulation that constitutes fisheries management in the real world.

The first incorrect assumption is that lawmaking somehow goes on in isolation from the struggle for resources that leads to fishery depletion. What lawmakers are theoretically supposed to do, whether they are regulators, legislators, or judges, is to identify market failures that lead to "tragedies of the commons" like fisheries depletion; once they discover these market failures, their job is to fashion regulations to correct them (Christy and Scott 1965, Hardin 1968, Cheung 1970). Market failures stem from a number of readily identifiable sources: free rider problems, jurisdictional incoherence, overly high discounts placed on future income from renewable resources, poor accounting of uncertain risks to the resources, and the difficulty of translating ethical or otherwise nonmonetary values into measures that can be balanced against the economic costs of fish left uncaught.

Lawmaking, however, is subject to all of the same kinds of market failures that the unregulated economy is. The legal system is a kind of market for legal entitlements to use resources in certain ways; inasmuch as people struggle in that legal market for rights to use resources, "the law" and "the market" are simply different modes of bargaining between economic actors (Hurst 1982). It is certainly true that much of what passes for resource management amounts to little more than one well-organized interest group or another pressing the state to give its members access to resources while denying it to others. Most restrictions on fishing gear fall under this head: the controversies between people who troll for salmon offshore, those who fish salmon inshore for recreation, and the Indian tribes should come immediately to mind.

California history is replete with examples of this kind of struggle for resources displaced from the market into the legal system. The California Fish and Game Commission spent most of the first 30 years of its history engaged in a process whereby it commissioned one or another scientific study of fisheries problems, noted the near-uniform conclusion that the one-third of the state's fishers who were Chinese were to blame for those problems, and with little trouble urged the state legislature to burden the Chinese fisheries with season restrictions, gear restrictions, export prohibitions, and so on.

As it turns out, Chinese fishing had little or nothing to do with any of the problems that led fishers of European background to demand that the state take legal action against them. In the 1880s, Chinese abalone hunters did well and Italian market fishers did poorly, for example, not because of any ecological link between the two, but because the fur industry had by that time wiped the California Current system clean of sea otters, which allowed populations of intertidal mollusks to bloom and thereby led to a depletion of the kelp forests that provided habitat for the market fishers' targets. Indeed, the record hints that, by the late 1880s, Chinese gathering had depressed populations of abalone and sea urchin enough that the kelp forests were reviving in those neighborhoods where the Chinese were active (McEvoy 1986). To contemporary observers, however, Italian trouble and Chinese success, plus the instinctive notion that Nature herself had only a passive role to play in the human economy, led to a political result in which resources management amounted to a struggle between harvesters only, in the state capitol no less than on the water itself.

Perhaps a more dramatic example of this reciprocal interaction between lawmaking and market struggle comes from the sorry history of the California sardine fishery. Here, California assembled the world's most sophisticated research-and-regulatory apparatus to manage what at the time was the most intensive fishery the world had ever seen (Thompson 1919). By the late 1920s, the California Fish and Game Department had identified all of the then-accepted signs of overfishing in the stock and recommended a catch limit of 250,000 tons (Clark 1939). Later research indicated that this was close to the fishery's sustainable yield at the time, even with discounting for occasional years of reproductive failure built in (Murphy 1966, MacCall 1979).

The problem was that the state legislature had the legal authority for regulating commercial, as opposed to recreational, fisheries: what happened was that the Fish and Game apparatus had to join the commercial fishery and (especially) its allies in the state's poultry industry in a political struggle over allocating access to the fishery. As a result, the fishery went essentially unregulated. In 1935, Oregon and Washington responded to California's inability to rein in its fishers by giving theirs unlimited access to the stock as well. By the end of the thirties, the sardine fishery was seriously overcapitalized and catches had leveled off; it collapsed suddenly in 1945-46 and again in the early 1950s, never to recover. Here was a particularly clear example of the reciprocally constitutive interaction between production and lawmaking: the"tragedy of the commons" reproduced itself, more or less unchanged, in the very regulatory processes that were supposed to correct its evil effects in the market.

If market struggle shapes the regulatory process by influencing the outcome of political bargaining in legislatures and administrative agencies, it also does so by influencing the character of the scientific information made available to lawmakers as a basis for their allocations. This in turn, takes place in two arenas, both by determining the kinds of questions that scientists are given to answer about a resource and by influencing the ways in which lawmakers respond to whatever information their scientists are able to generate for them.

In the nineteenth century, both state and federal fisheries science concentrated single-mindedly on increasing the flow of resources from the environment into the market. One way to do this was through prospecting for new resources; a great deal of this kind of activity occurred at all levels of government in the last three decades of the century.

Another way to maintain the flow of resources into the market was to enhance the productivity of declining fisheries through applied science. Government scientists, then, restocked depleted waterways with exotic species of fish and propagated particularly valuable species like salmon and trout artificially, in government hatcheries. As it turned out, a few successful transplants of exotic fishes to California waters (shad and striped bass) were at least counterbalanced by the baleful effects of others (German carp and brown catfish, most notoriously) (Smith 1895, Elton 1958). Observed increases in the salmon harvest at the turn of the twentieth century, meanwhile, were almost certainly due, not to the hatchery work, but rather to changes in climate, changes in the distribution of the salmon's prey species, the opening of an offshore troll fishery for immature salmon, and the steady decline of pollution from the mining industry inshore (Larkin 1979, McEvoy 1986). The state, however, claimed in 1900 that "by the efforts of this Commission, the salmon has been restored to our state" (California Fish and Game Commission 1900).

Not only to harvesters, then, but also to the public officials whose job it was to oversee the industry, fish were like gold nuggets: valuable commodities to be recovered from their state of nature and transformed into cash for the one, a valuable source of political capital for the other. So long as government apparently maintained the supply and drove unwanted competitors out of the business, further inquiry into the biology of valuable fisheries seemed to have little point. Nature was thoroughly plastic and could be manipulated in the service of enterprise to the limits of human ingenuity and political will. That observed changes in the fishing business might have been due to the collective behavior of the harvesters, to changes in other industries, or even to the weather was simply not a legally meaningful question. Inasmuch as most fishery research was paid for through political appropriations, moreover, it was not a scientifically meaningful one, either.

The second way in which the interaction between lawmaking and market struggle influences the role of fisheries science in management has to do with the effects that knowledge has on the regulatory process. Here again, a telling example comes from the history of the sardine industry. The sardine is very vulnerable to environmental change in its first few days after hatching: if conditions aren't just right while fish are in the larval stage, the whole generation will die (Smith 1985). What happened was that conditions were good for sardine recruitment between 1900 and 1940, while the sardine fishery was in its growth phase, but when conditions turned bad in the 1940s, the stock could no longer sustain such a heavy draft as the industry was placing on it and collapsed. What extinguished the sardine, then, was the interaction between an overcapitalized fishery and a volatile ecology (Murphy 1966, MacCall 1979). Precisely the same thing happened in Peru some 30 years later (Clark 1977).

Until the mid-1960s, one could take either of two positions in the political controversy over regulating the sardine fishery. One could say that observed fluctuations in the harvest were caused by "environmental" conditions, meaning that fishing had nothing to do with the collapse and that the collapse would have taken place even had no fishing been done at all. Alternatively, one could take the position that observed fluctuations in the harvest and the ultimate collapse were due to overfishing (Croker 1954, Clark and Marr 1955).

Although some people had pointed to possible interactions between fishing and environmental change, they were unable to bring that reasoning to bear on the political process because neither casual synergy nor predicting the future on the basis of random-variable analysis were meaningful concepts in the culture at large. By the mid-1960s they were, thanks largely to the work of Rachel Carson in popularizing the ecosystemic effects of chemical pesticides and to the way in which fallout from atmospheric nuclear weapons testing had familiarized the American public with food chains. Computer modeling for predicting the weather, the outcomes of elections, and the public health effects of this or that pollutant also contributed to educating the public about the ecological and cybernetic concepts that underlay what is now generally accepted as the explanation for the sardine failure, first published in 1966.

Also coloring the debate over the sardine collapse in the mid-1960s was an industry campaign to open the state's anchovy fishery to commercial harvest (McEvoy 1986). The anchovy had apparently grown abundant as it filled the ecological niche left vacant by the depleted sardine (Murphy 1966). The industry argued that the state could promote the eventual recovery of the more valuable sardine by allowing it to fish down the anchovy population. At this point, one important scientist wrote to a friend in the industry that the time had come to switch sides on the sardine issue: not only would that open up the anchovy fishery, but, in his words, "the sardine case is beginning to look too sound to me for us to either hide from the public or to escape the conclusions of." This statement was only partly about the scientist's knowledge of the world; the scientific judgment here was primarily an assessment of the political consequences of admitting the truth of one or the other position in a scientific debate. An end to the sardine controversy was made possible by some absolute advance in the scientific knowledge about the fishery, but the legal cognizability of that knowledge was a political function. In the event, the pro-development scientists traded a moratorium on sardine fishing for an experimental anchovy fishery; so enthusiastic was the legislature for this new approach to fisheries management that it enacted similar moratoria on a number of other depleted fisheries without any real scientific basis for doing so.

Conclusion

Our scientific knowledge of the world, then, emerges out of a complex interaction between ecology, economic production, and the legal system. What "science" is, then, is a struggle among those who do research and between researchers and those who put their findings to work over what will count as "reality." Lawmaking, in turn, consists of a struggle between people wanting to allocate access to resources in particular ways, whether to commercial use, recreational use, or for "natural" uses. Production, for its part, is a complicated function of technology, the sociology of user groups, the structure of legal entitlements to access, and the availability of resources. Nature is, finally, at any point to no small degree the product of past and present human impacts on it, which impacts in turn are determined in no small way by the sociology and the legal structure of the market.

As Muir had it, everything is connected to everything else. Historically, fishery managers have made trouble for themselves when they have assumed, usually unconsciously, that this statement is not true. Although theory and technology of fisheries management have advanced a great deal since the late nineteenth century, some of these conceptual divisions between lawmaking and the private market, between science and politics, and so on persist, usually in ways of which scientists and lawmakers are not even aware. Those assumptions are, indeed, so powerful precisely because they are made instinctively, unthinkingly. Their unseen power is all the more reason why fisheries managers should be careful to watch out for them when they ask themselves such questions as, "What exactly are we trying to sustain here?"

To conclude, one way of answering the organizing question for the symposium is to say that, to the extent that fisheries managers approach their task as if they were trying to maintain sustainable yields of guppies from a well-maintained aquarium, they are doing it wrong. Coming up with a better way of thinking about the problem is hard because all the dualisms that underlie our traditional thinking about the world, between culture and nature and law and markets and so on, are so deeply embedded in our culture and our legal system that it is sometimes hard to tell when they are at work in our thinking. Some lessons, however, may be worth taking away from this excursion into the history of California's fisheries.

At a minimum, mathematical certainty about the state of the resources, or about the likely effects of whatever regulations a government might actually impose on a fishery, is simply not attainable. This lack of certainty is partly because of the important role that random shocks play in the environment and should play in our thinking about it. It is also because of the sheer complexity of the tripartite system of ecology, production, and management, in which we are inextricably embedded; our knowledge of the system will always be imperfect because we will change it every time we act in it.

Another thing that may be said is that traditional strategies for management, insofar as they assume any of these dualisms, are likely as not to raise as many new problems as old ones that they solve. Public agencies will of course have to do a certain amount of prospecting work, and they will always have to balance competing claims for access to resources. But they should never delude themselves into thinking that all of that, even taken together, is "management" in the way that it really should be approached.

Finally, what we ought to sustain when we approach fisheries management is not the size of a particular stock nor even the prosperity of a particular harvesting group over the near or long term. Rather, the most important target is the long-term health of the interaction between nature, the economy, and the legal system. We can recognize that diversity and balance in the system, insurance against an uncertain future, the social cohesion of user groups, the attachment that fishers feel for their work, even the moral unease we feel when we contemplate the extinction of a species, all those difficult-to-quantify things do in fact play integral roles in the tripartite interaction between ecology, production, and management, and perhaps more significant ones than the more "objective" measures to which we usually look for guidance. We can recognize that, because everything is connected to everything else, every step we take will change the system in which we live in some way. When we make choices, then, we can keep an eye on what kind of interactive relation we want to maintain with the rest of Creation and make our choices accordingly.

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Throughout their history, conservation science and sustainable-yield management have failed to maintain the productivity of living resources. Repeated overexploitation of economic species, loss of biological diversity, and degradation of regional environments now call into question the economic ideas and values that have formed the foundation of scientific management of natural resources. In particular, management efforts intended to maximize production and ensure efficient use of economic "resources" have consistently degraded the larger support systems upon which these and all other species ultimately depend. This series of essays examines the underlying historical, cultural, and philosophical issues that undermine sustainability and proposes alternative approaches to conservation. These approaches emphasize the relations among populations rather than among individuals; the integrity of whole ecosystems across longer time frames; the importance of qualitative as well as quantitative indicators of human welfare and sustainability; and the unpredictable and interdependent interactions among "natural," scientific, and regulatory processes.

Keywords: Environmental ethics, environmental history, fisheries management, resource conservation, resource economics, sustainability.

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