

ECOLOGICAL HEALTH AND THE NORTHERN FOREST

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Many different images are invoked by the term "The Northern Forest." To some, the Northern Forest is a vast region of trees that for centuries has supported a rural, timber-based economy. To others, it is a heterogeneous expanse of forest ecosystems that supports a diverse and unique set of biological communities. To still others, it is an outpost from restrictive government controls that relentlessly erode personal freedoms.

Similarly, many different images are conjured by the phrase "the debate over the future of the Northern Forest." Historically, the focus of the Northern Forest Lands Study ("NFLS") and the Governors' Task Force ("GTF") was primarily on the economic status of the region. Particular attention was given to the existing forest-products industries and the factors that influenced their economic health, such as the trend towards conversion of land to non-forestry uses (primarily second home development), property taxes, and incentives for investment in timberland ownership.¹ The ecological health of the region was addressed solely by listing features of natural history and geography, such as the number of lakes, miles of rivers, and number of unique vertebrate species.²

The Northern Forest Lands Council ("NFLC"), the successor to both the NFLS and GTF, was also formed with a primarily economic focus in mind. The Council identified its mission as being the "reinforce[ment] of traditional patterns of land ownership and uses of large forest [areas in the Northern Forest region]."³ Within its Mission Statement the Council identified three approaches it would take to achieve its primary goal. The first two approaches placed strong emphasis on improving economic conditions:

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1. See STEPHEN C. HARPER, ET AL., U.S. DEPT OF AGRIC., THE NORTHERN FOREST LANDS STUDY OF NEW ENGLAND AND NEW YORK (1990) [hereinafter NFLS].

2. *Id.* at 22-27.

3. NORTHERN FOREST LANDS COUNCIL, FINDING COMMON GROUND: CONSERVING THE NORTHERN FOREST (1994) (Mission Statement) [hereinafter COMMON GROUND].

- Enhancing the quality of life for local residents through the promotion of economic stability for the people and communities of the area and through the maintenance of large forest areas; and
- Encouraging the production of a sustainable yield of forest products.

Yet despite the Council's predominant focus on the economic health of the forest-products industry, the third approach identified in its Mission Statement related in part to the importance of ecological conditions in the region:

- Protecting recreational, wildlife, scenic, and wildland resources.

It is my feeling that this third approach addresses one of the most fundamentally important issues for the future of the Northern Forest—its ecological health. As I will argue more fully below, maintaining ecological health ought to be the greatest priority for any society. Yet I also feel that the NFLC did not take full advantage of its opportunity to investigate this topic. Given the articulation of this third approach within its mission statement, the Council was in a perfect position to focus resources and attention on the development of significant and objective ecological findings. However, the status of ecological health in the region was never assessed with actual data, and the final year of the Council's work was dominated by debate over conservation strategies fueled largely by undocumented statements.

For example, Malcolm Hunter, of the University of Maine, when asked by the NFLC his opinion about the status of biological diversity in the region, simply said "[it is] poor and declining,"⁴ while Rainer Brocke, of SUNY Syracuse, in response to the same question, said that "[c]oncerning biodiversity, there is good news in the Northeast!"⁵ Similarly, in *The Future of the Northern Forest*, a collection of essays by participants in the

4. MALCOLM L. HUNTER, JR., NORTHERN FOREST LANDS COUNCIL, PROCEEDINGS FROM THE BIOLOGICAL RESOURCES DIVERSITY FORUM 3 (1992).

5. RAINER H. BROCKE, NORTHERN FOREST LANDS COUNCIL, PROCEEDINGS FROM THE BIOLOGICAL RESOURCES DIVERSITY FORUM 15 (1992).

Northern Forest debate, Jonathan Wood, a forester from northern Vermont said "[t]he Northern Forest is the focus of attention and worthy of recognition because of the past history of management by private landowners. . . . The heated debate that has been generated by concern for this land is a compliment to the stewardship ethic of our parents and grandparents."⁶ Yet Jamie Sayen, Director of the Northern Appalachian Restoration Project said "[t]oday, the forests of the Northern Appalachians are, by and large, in the worst condition they have been in since the retreat of the ice more than ten millennia ago."⁷ At best, statements made over the past six years about the ecological health of the Northern Forest, both positive and negative, were made from astoundingly incomplete data sets.

Now, at the end of the NFLC's work, many people still do not understand what the issue really is, why it is important, what the existing data tell us about the ecological health of the Northern Forest, and what it is we still do not know.

The focus of this paper relates to these points. In Part I, I briefly review why the ecological health of the Northern Forest ought to be considered in all discussions that continue from the work of the NFLC and how such considerations could more successfully be carried out. In Part II, I review some of the available data relating to the region's ecological health. Finally, I conclude that a focus on ecological health in any policy process, especially one associated with the Northern Forest, necessarily serves as a real indicator of how we are doing as a society. It is my hope that this will contribute to bettering the effectiveness of all future work and to blunting much of the unscientific rhetoric about ecological conditions here.

6. Jonathan Wood, *A Sustainable Resource For a Sustainable Rural Economy*, in *THE FUTURE OF THE NORTHERN FOREST* 157 (C. McGrory Klyza & S.C. Trombulak, eds., University Press of New England 1994).

7. Jamie Sayen, *A Vision of Sustainable Natural and Human Communities in the Northern Forest*, in *THE FUTURE OF THE NORTHERN FOREST* 178 (C. McGrory Klyza and S.C. Trombulak, eds., University Press of New England 1994).

I. ECOLOGICAL HEALTH

A. *Why It Is Important*

It is vital that policy-makers as well as a majority of the participating public recognize that maintaining the ecological health of this, and any region is of paramount importance. Several arguments can be made in support of this claim.⁸

First, the long-term viability of a society depends on its ability to support its resource needs. All societies are to some extent dependent on natural resources, such as wood, water, soil, and the plants and animals that provide food, medicines, and industrial products. Societies that overexploit these resources, or use them in ways that degrade production, decline or collapse altogether.⁹ This decline occurs inevitably and indicates the fallacy of considering ecological (or biological) reality as being equivalent to political or economic traditions. A society may transform its traditions, but it cannot transcend the laws of nature.¹⁰ With respect to the Northern Forest and the goals of the NFLC, maintenance of economic stability and traditional patterns of land usage depend completely on the maintenance of forest health. Note that I use the term "forest" in a broader sense than just the trees.

Second, a decrease in ecological health increases the amount of capital that society must expend to maintain a given standard of living to replace ecosystem functions that are lost. Ecosystems demonstrate natural processes that minimize erosion, remove toxins from water and air, and recharge ground water. If these processes are eliminated, we are forced to divert money to replacing those processes, either through ecological restoration or technological development. In my opinion, taxpayers in the

8. It is by no means necessary that anyone believe all of the arguments. Each relates to slightly different ethical beliefs and I doubt that anyone will hold them all. Yet, I think it likely that the vast majority of people hold at least one of them, and therefore ought to support the goal of maintaining ecological health. See also BRYAN NORTON, *WHY PRESERVE NATURAL VARIETY?* (1987) (discussing the relationship between ethical beliefs and the goal of maintaining ecological health).

9. See generally JOHN PERLIN, *A FOREST JOURNEY: THE ROLE OF WOOD IN THE DEVELOPMENT OF CIVILIZATION* (1989) (discussing the collapse of societies that overexploited their forests).

10. Stephen C. Trombulak, *Political Tradition Must Reflect Scientific Reality*, 2 *NORTHERN FOREST FORUM* 6, 4 (1994).

Northern Forest already feel the fiscal burdens associated with decreased water quality and increased erosion.

Third, the long-term viability of an industry based on a renewable resource (such as the forest-products or fishing industries) depends on maintaining conditions that allow the resource to renew itself at a rate compatible with the needs of the industry. Many parts of the region are already witnessing the effects of economic dislocation due to actions taken by forest-product companies, actions driven in part by changes in the commercial value of the forests.¹¹

Fourth, humans are different than all other species on Earth and therefore have a responsibility (based on religious or ethical precepts) to be good stewards of the land, air, waters, and all other life forms. This is the philosophy that Wood posited was the central element in determining how earlier generations of residents in this region treated forest ecosystems.¹²

Fifth, humans are but one species among the more than one million present on Earth, and we have no moral right to cause extinction. This is similar to my fourth point, but framed as a proscription against behaviors that work against ecological health, rather than as a mandate for behaviors that promote it.

Sixth, a decrease in ecological health decreases the aesthetic quality of a region, degrading the quality of life. Obviously, there are some people who prefer to live in highly urban environments, such as New York City or Los Angeles, rather than in the rural Northern Forest region. But it is fair to assume that the residents of the Northern Forest are not among them. Maintaining ecological health maintains the characteristics of the environment that make this region a desirable place for these people to live.

Given these arguments, one is hard pressed to articulate an argument *against* the maintenance and restoration of ecological

11. See Henry Swan, *A Multi-Use Working Forest*, in *THE FUTURE OF THE NORTHERN FOREST* 199 (C. McGrory Klyza & S.C. Trombulak eds., 1994) (discussing how overharvesting has depressed opportunities for timberland investment in the Northern Forest); see generally MITCH LANSKY, *BEYOND THE BEAUTY STRIP: SAVING WHAT'S LEFT OF OUR Forests* (1992) (discussing the relationship between abusive forestry practices in Maine and the economic decline of the forest-products industry there); MICHAEL WILLIAMS, *AMERICANS AND THEIR FORESTS: A HISTORICAL GEOGRAPHY* (1989) (discussing the economics of the forest-products industry in the United States and how it has influenced and been influenced by forest ecosystem health).

12. WOOD, *supra* note 6, at 157.

health in the Northern Forest other than a desire to focus solely on short-term gains in one or a few economic sectors without consideration for long-term regional economic or social conditions.

This overall line of reasoning has been seriously misinterpreted to mean that the scientific community should tell us what we must do. Some have taken offense that scientists should choose to act as technocrats, removing from the citizenry their right to debate their own future.¹³ Offense would be warranted if this indeed was what scientists were saying. Rather, science offers society a means to achieve its goals and avoid undesirable future events. A scientific analysis can indicate what the likely outcomes are of specific courses of action. Such analyses are not a restricted domain of the natural sciences, and can be carried out by the social sciences as well. To rephrase the six points made above, analyses of past events and ecosystem processes strongly indicate that policies that do not promote ecological health will lead to economic pressure, industrial dislocation, erosion of the quality of life, and cultural decline or collapse. This is not to say that we have no choice except to promote ecological health or that we should not debate the issues. It merely suggests what our options are. The choice is left to society to decide its course of action.

Without ecological health, all social issues are irrelevant. The primary focus for us now as a society must be on the following questions: What is the status of ecological health of the region? What are the causes of any ecological condition deemed "bad" (a concept discussed below)? What kinds of modifications to ecosystems can be made without creating negative impacts? And, what kinds of socioeconomic traditions can we adopt without causing ecological disruption?

B. Concepts, Confusions, and the Scientific Method

Before we can conduct a meaningful analysis of the ecological health of the Northern Forest, it is necessary to develop a clear understanding of what we are trying to assess and how we can go about it. An understanding of this concept actually requires a review of other concepts that have been advanced within the conservation community over the past several years. The most

13. James L. Huffman, *Managing the Northern Forests: Lessons from the West*, 19 VT. L. REV. 477 (1995).

recognizable of these is that of "biological diversity" or "biodiversity."

Despite claims to the contrary, the concept of biological diversity is well understood and has a clear definition. The NFLC recognized this and stated it as the first finding of the Biological Resources Subcommittee, as it adopted Hunter's definition:

Biological diversity or biodiversity is: "[t]he diversity of life in all its forms, and at all levels of organization. 'In all its forms' reminds us that biodiversity includes plants, invertebrate animals, and microorganisms, as well as vertebrates that garner most of the attention. At 'all levels of organization' indicates that biodiversity refers to the diversity of genes and ecosystems, as well as species diversity."¹⁴

This definition is made more complete by including the processes that link life forms, such as predation, competition, decomposition, and disturbance.

A focus on biological diversity is more meaningful for conservation efforts than is a focus on endangered species alone.¹⁵ The conservation community's focus on biological diversity represents a major advance for two reasons. First, it focused attention on levels of organization beyond the species level, particularly ecosystems. Unfortunately, the species level of organization still receives the greatest weight of protection under the law.¹⁶ With the exception of wetlands, ecosystems are not currently afforded similar protection. Yet further development of ecosystem protection and management plans would be even less likely without this advance. Second, this focus set the stage for considering natural patterns of distribution and abundance as standards against which scientists assess conservation strategies.

It is unfortunate that the concept of biological diversity has been misinterpreted or misrepresented by many involved in

14. COMMON GROUND, *supra* note 3, at A-23.

15. Reed F. Noss, *From Endangered Species to Biodiversity*, in BALANCING ON THE BRINK OF EXTINCTION: THE ENDANGERED SPECIES ACT AND LESSONS FOR THE FUTURE 227-46 (K.A. Kohm, ed., 1991).

16. See generally Endangered Species Act, 16 U.S.C. §§ 1531-1543 (1984); Marine Mammal Protection Act, 16 U.S.C. §§ 1361-1407 (1984); Convention on International Trade in Endangered Species of Wild Fauna and Flora, March 3, 1973, 27 U.S.T. 1087, T.I.A.S. No. 8249.

discussions on the Northern Forest. It has, for example, been implied that biological diversity is improved by increasing the number of individuals of a species or increasing the number of species in an area without regard to whether the population levels are beyond their normal range or whether the species is even native.¹⁷

It has also been said in numerous public hearings that biological diversity cannot be quantified or measured, and is therefore a meaningless concept. There are several possible interpretations of this objection. One is that biological diversity cannot be assigned a value. This is incorrect. In any particular geographic area the biological diversity can be assigned several values, including measures of the number of species or ecosystems present (richness), the relative abundance of each species or ecosystems (evenness), and the degree of genetic variation within populations of organisms (genetic heterozygosity).¹⁸ It is necessary only to identify the level and type of diversity of interest to quantify it.

Another interpretation of the objection is that the several different measures of diversity make it impossible to assign some kind of universally-accepted "biodiversity quality" ranking, ranging between good and bad. This is true, and is no different than for any other social goal, including human health, economic development, national security, or standard of living. It is important then to realize that measures of ecological health include, but are not limited to, measures of biological diversity.

As stated above, implicit among conservation biologists is the understanding that considerations of diversity, especially as they relate to the development of conservation policy or environmental law, are framed in the context of natural or native conditions. However, the concept of "natural" was a problem for the NFLC. Ecological conditions in the region should ideally be compared against some "natural" baseline, and would provide support for or

17. Michael Coffman, *Managing for Diversity in a Working Forest*, Presentation at The Natural Areas Association Annual Meeting, Orono, Me. (June 22-26, 1993); Hugh Canham, *Optimal Management of Forest Landscapes for Maximizing Biodiversity and Regional Economic Viability: The Case for Laissez-Faire Private Ownership*, Presentation at The Northern Forest Lands & The Law, Symposium, Vermont Law School, South Royalton, Vt., (Sept. 30, 1994).

18. See ANNE E. MAGURRAN, *ECOLOGICAL DIVERSITY AND ITS MEASUREMENT* 7-9 (1988).

against particular policy recommendations. However, what is "natural"?

This proved to be so problematic that the Council decided to consider the present time as the baseline: "[t]he Council's recommendations are designed to conserve the present diversity and enhance it where possible."¹⁹ Ecological conditions in the past would not be considered. (It is obvious that this restriction was not applied to other areas of the Council's investigations. For example, how could one make the argument that real estate development was an emerging issue in the region, one that threatens traditional patterns of land ownership, if one does not reference patterns of development in the past). I call this the "natural is irrelevant" philosophy. But since all of humanity's recorded history indicates that all societies that deviated too far from the laws of nature (i.e., natural laws) either declined or collapsed altogether, an ability to identify what is natural and use it in the political arena is clearly relevant.²⁰

A second philosophy is that, with respect to the Northern Forest, "nothing human is natural." This also has the effect of making the concept irrelevant in establishing priorities and policies. Since we cannot stop being human, such a philosophy would force us to ignore the concept altogether, which again is not in our best interest.

A third philosophy, functionally equivalent to the first two, is "everything is natural." This philosophy is founded on the principle that since humans are a part of nature, anything humans do must be natural. As logical as this seems, it leads to the conclusion that since humans make thermonuclear weapons, the thermonuclear destruction of life on Earth is a natural act. This may be logically correct, but is functionally meaningless. It reduces everything in the Universe to being natural and renders the concept useless for developing policy.

Since most people accept that humans are a part of and not separate from nature, and intuitively feel that death by thermonuclear war or a gunshot wound is *not* a natural death, we must either accept that the term "natural" can be defined within a limited domain or abandon the term altogether.

19. COMMON GROUND, *supra* note 3, at 61.

20. See generally PERLIN, *supra* note 9.

A step towards the first alternative has been made by J.E. Anderson, who offered three measures of natural conditions that could be quantified:

- (1) the degree to which the system would change if humans were removed;
- (2) the amount of cultural energy required to maintain the functioning of the system as it currently exists; and
- (3) the complement of native species currently in the area compared with the suite of species in the area prior to settlement.²¹

Naturalness, by these measures, becomes a spectrum rather than a single end-point or value. A region, then, is not "natural" or "unnatural" in and of itself. Rather, it is necessary to evaluate the naturalness of a region relative to some other condition. For instance, it is possible to assess the natural quality of a particular area by evaluating that region in relation to a similarly situated region or to the same region at a different point in time.

Despite the increased attention paid to the importance of regional biological diversity in the final year of the NFLC's discussions, many people still failed to grasp its full meaning. This failure highlights the need for the conservation community to begin to articulate a more encompassing concept, one that comes closer to the actual goal towards which society must strive: biological integrity.

Like the concept of private property rights,²² biological integrity cannot be defined by a simple phrase but instead must be described as a set of conditions. At a minimum, biological integrity is increased in an area when the following conditions are met:

- (a) All ecosystem types and successional stages are represented across their natural range of variation;

21. Jay E. Anderson, *A Conceptual Framework for Evaluating and Quantifying Naturalness*, 5 CONSERVATION BIOLOGY 347-352 (1991).

22. John A. Humbach, *Law and a New Land Ethic*, 74 MINN. L. REV. 339-370 (1989).

- (b) Viable populations of all native species are represented in natural patterns of abundance and distribution;
- (c) Ecological and evolutionary processes, such as disturbance, nutrient and water cycling, and predation, are maintained; and
- (d) The biological diversity in the region can respond naturally to change.²³

The concept of biological integrity thus combines elements of the definitions of biological diversity understood by the general public (e.g., numbers of species) and by conservation biologists (diversity at the genetic, species, and ecosystem levels), and recognizes the importance of ecosystem processes and such ecological principles as non-equilibrium conditions, exotic vs. native species, and evolution.

It is my perception that the general public is becoming much more aware of the importance of "biodiversity." Therefore, substituting concepts in a policy arena is not without its public relations risks. However, recent history offers several examples of how the term "biodiversity" has been misunderstood or misapplied in setting conservation policy. For example, the White Mountain National Forest Management Plan of 1986 called for large-scale manipulation of forest conditions to enhance the number of species on the local level, regardless of whether those species would normally be found there or at the numbers promoted by the management plan.²⁴

Misunderstanding also exists among conservation biologists themselves. One of the most heated debates within the academic conservation community in the 1980's was whether it was better for biodiversity to develop ecological reserve systems that were comprised of a single large or several small reserves (known as the "SLOSS" debate).²⁵ This debate was predicated to a large

23. Reed F. Noss, *The Wildlands Project: Land Conservation Strategy*, WILD EARTH, at 11 (Spring Special Issue 1993).

24. See Emily Bateson, *Sustaining Our Forest—Crafting Our Future*, in THE FUTURE OF THE NORTHERN FOREST 149 (C. McGrory Klyza & S.C. Trombulak, eds., 1994).

25. ECOLOGICAL PRINCIPLES OF NATURE CONSERVATION: APPLICATIONS IN TEMPERATE AND BOREAL ENVIRONMENTS, 82-84 (L. Hansson, ed., 1992).

extent on the false assumption that the only goal in conservation was to maximize the number of species preserved without regard to what the species were, what their role was in the ecosystem, or even how ecosystems interacted with each other. These examples suggest that, despite the challenges, it will be better to continue our education of the public and promote a better appreciation of the importance of biological integrity.

It is my hope, of course, that we will remember the lessons learned in our efforts to incorporate into policy discussions considerations of biological diversity. Biological integrity can be defined, but the definition will be comprised of a series of conditions. Biological integrity can be measured, but because it is defined as a series of conditions it will have a series of measures. And biological integrity of a region cannot be assigned an index ranking.

This leads finally to consideration of the concept of ecological health, the central topic of this paper. Simply put, ecological health is a composite measure of biological integrity. It is similar to the concept of human health. The greater the integrity of a person's body, the greater is the person's health. The greater the biological integrity of an area, the greater its ecological health.

Recognition by the NFLC, and a majority of the public who actively participated in the Northern Forest discussions, of biological diversity as a legitimate topic for the Council's studies constituted an important first step in the policy making process. However, the potential for the Council to make significant contributions to such an analysis quickly disappeared because participants in the discussions made a host of errors reflecting an inability or lack of willingness to address the subject in a constructive way. The findings of the Biological Diversity Subcommittee are vague and succeed at avoiding specific, documented statements of fact.²⁶ In the end, the Council's recommendation to promote wildlife and wildland resources in the Northern Forest is without any direct, significant conservation value.²⁷ What follows is a partial list of suggestions that will help us to avoid these errors in future discussions on the topic, especially those that will hopefully grow out of the NFLC process.

26. COMMON GROUND, *supra* note 3, at A23-A26.

27. *Id.* at 62-63.

C. *Guidelines For Discussing Biodiversity in the Northern Forest*

1. Define the Terms

In an effort to prove a point, people often provide synthesized interpretations of data that support their points. Statements that the status of ecological health of the Northern Forest is "bad" or "good" are meaningless without an indication of what is meant by those terms. Are conditions bad if even one species is endangered or the area experiences *any* disturbance? Are they good as long as a few species are abundant and the hillsides are generally green in the spring?

2. Define the Domain

Malcolm Hunter Jr. and Rainer Brocke, participants in the Biological Resources Diversity Forum of the NFLC, disagreed in their written assessment of the ecological health of the region in part because their statements related to different domains, both in space and time. Hunter assessed conditions in the state of Maine, an area characterized by large-scale industrial forestry and few ecological reserves.²⁸ Brocke referred to conditions in the Adirondack Park, over twenty percent of which is designated wilderness.²⁹ Furthermore, Brocke was comparing conditions today to those of 100 years ago at the height of large-scale cutting in that region, while Hunter was referring to conditions relative to what they would be under more natural conditions. Both Hunter and Brocke offered correct analyses. The apparent difference between them is explained by identifying the *domain* of their answers. The conceptual problem of defining domain is further illustrated by considering the term "forest." To some, it refers solely to the trees; to others, it is the entire ecosystem.

3. Base Assertions on Data

If a statement cannot be quantified, it is just an opinion, and provides only weak justification for the development of policy. There are, however, subtle aspects to this advice. First, one needs

28. HUNTER, *supra* note 4, at 3.

29. BROCKE, *supra* note 5, at 15.

to present all of the available data on as many parameters as possible, not just a subset that supports a preconceived opinion. What is the status of trees in the Northern Forest? There are several dimensions to this question; for example, how many trees exist, what percentage of the total area constitutes forested land, what is the tree size and age distribution, what are the species diversity and richness at specific locations, and whether past baseline conditions in the past are being compared to specific values (e.g., there is 200% more forested land in Vermont today than in 1850) or continuous trends (e.g., the amount of forested land has not increased since the 1950's). It is merely self-serving to present—or believe—only data that support your predetermined view.³⁰

Second, when one makes the statement “[t]here is no evidence that such-and-such is true,” one must indicate whether this is the case because there is no data—in which case the statement could be true but no one has investigated it—or because the existing data do not support the conclusion. These two situations ought to have very different consequences in the development of policy and the establishment of research priorities.

4. Understand the Basic Principles of How Ecosystems Function

One cannot assess the health of ecosystems without understanding how they operate. Although ecologists still debate many of the details of ecosystem function for particular systems, many basic principles have already emerged and are well accepted.³¹ These principles include:

- (a) ecosystems change over time;
- (b) all components of an ecosystem are directly connected to at least one other component, and therefore indirectly to everything else;

30. Stephen C. Trombulak, *A Plea for Biological Honesty*, WILD EARTH 6-7 (Winter 1993-94).

31. See ROBERT E. RICKLEFS, *THE ECONOMY OF NATURE* 101-174 (3rd ed., 1992) (generally discussing ecosystem science).

- (c) important processes occur over both large and small scales;
- (d) many species are dependent on disturbance, often at specific scales in space and time; and
- (e) ecosystems will often be stable in more than one state but never in an infinite number of states.

Assessments of ecological health that ignore these principles are flawed.

5. Understand the Basic Principles of Science

Science is nothing more than a method of answering questions. It is distinguished from other such methods by the following features: it is replicable, statements can be shown to be false, and statements are accompanied by probabilities of being incorrect. This last point is the most important with respect to establishing policy. There is always a chance that what we believe to be true is, in fact, incorrect; additional data may reduce this chance, but it will never eliminate it.

This lack of absolute certainty might be cited as a reason why science should not play a central role in the development of policy. Yet this lack of certainty is true for all methods of answering questions. Unlike them, however, the scientific method permits an evaluation of the level of certainty, which is essential if society is to set priorities successfully.

II. AN INITIAL ASSESSMENT: ECOLOGICAL HEALTH AND THE NORTHERN FOREST

To demonstrate some of these principles and how consideration of the protection of wildlife and wildland resources should have been conducted, I will conclude this paper with a framework for analyzing the ecological health of the region, as well as a review of some of the available data. This framework involves analysis of baseline conditions, patterns of diversity at the species, genetic, and ecosystem level, and assessment of ecosystem functions.

I will not consider here the Northern Forest in its strict political sense for three reasons. First, the Northern Forest as it

is defined makes little ecological sense.³² Ecosystems vary throughout the region and extend extensively outside of the region. Second, most data are easily available for states, less easily available for counties, and non-existent for townships. Third, conditions within Maine, New Hampshire, and Vermont as aggregates are probably fair (although not perfect) representations of the Northern Forest portion of each of those states. Aggregate conditions in New York, however, probably do not reflect conditions in Adirondack Park and Tug Hill. Therefore, much of the data I review more accurately relates to northern New England rather than the Northern Forest alone.

This type of assessment requires a regional perspective on information, and therefore differs from scientific studies that seek to establish causal or correlative relationships between factors through an experimental approach. It seeks to establish or document patterns within a large, geographic region, but is generally unable to explain why a pattern might exist. On the other hand, an experiment cannot document a regional pattern but might help to explain the existence of a pattern. For example, a large-scale monitoring program on the abundance of amphibians might demonstrate a regional decline, but not what factors are responsible for the decline. An experiment in a local area might demonstrate that the population density of amphibians is sensitive to soil pH and forest clearing, but not that amphibians are actually in decline throughout a region. Both approaches are vital, but the importance of the former has only been recently widely appreciated.³³

A. *Baseline Conditions*

A scientific approach to any issue is characterized by comparing some condition to a reference condition. In an experiment, for example, conditions following an experimental treatment are compared to those of a control group. In a regional analysis of ecological health, the reference state is the set of conditions that would be found in the absence of large-scale anthropogenic disturbance. While recognizing that ecosystems

32. Stephen C. Trombulak, *A Natural History of the Northern Forest*, in *THE FUTURE OF THE NORTHERN FOREST* 11-12 (C. McGrory Klyza & S.C. Trombulak, eds., 1994).

33. Winifred B. Kessler, et al., *New Perspectives for Sustainable Natural Resources Management*, 2 *ECOLOGICAL APPLICATIONS* 221-223 (1992).

change even in the absence of anthropogenic effects, the closest we can come to establishing what these conditions would be is to describe what conditions were prior to the onset of region-wide disturbance. Too few undisturbed ecosystems are left to do otherwise.

Such baseline descriptions are hard to come by for the Northern Forest region. What we do know about landscape-scale patterns here prior to modern times comes from two sources: a sparse written history and the paleoecological record.

The written natural history of this region is sparse because early explorers and colonists were less interested in documenting conditions than they were in establishing colonies and initiating trade with England. Credible reports on the natural history of New England and the neighboring maritime region of Canada are available from Rosier (1605), Biard (1616), Lescarbot (1618), Merton (1632), Wood (1634), Josselyn (1672), Denys (1672), and Le Clercq (1691), whose observations are summarized by William Cronon.³⁴

These authors describe a landscape best characterized by its heterogeneity and abundance. Spawning runs of smelt, sturgeon, alewives, and other anadromous species were so large that the fish could hardly fit into the streams. Waterfowl were easily killed by the dozens at a single spot, and individual flocks of a single species—the passenger pigeon—were measured in the millions. Trees were numerous and large. It was noted by Wood that many trees were thirty feet tall before their first branches spread. The average height of mature forests was over 100 feet, and a few trees were five feet in diameter and 250 feet tall. Forests were dense and changed composition over very short distances, presumably in response to local environmental conditions.

Forest conditions like these were still present in some locations of northern New England by as late as the mid-1800's. Thoreau reported that "[t]he surface of the ground in the Maine woods is everywhere spongy and saturated with moisture. I noticed that the plants which cover the forest floor there are such

34. WILLIAM CRONON, *CHANGES IN THE LAND: INDIANS, COLONISTS, AND THE ECOLOGY OF NEW ENGLAND* (1983) (summarizing colonial reports on the natural history of New England and the Maritime region of Canada).

as are commonly confined to swamps with us [in Massachusetts]."³⁵

The paleoecological record provides a picture that spans more time but emphasizes only patterns of change and the prevalence of disturbance. Pollen and macrofossil records demonstrate that following the retreat of the last glacier from this region, the vegetation transformed slowly from tundra to forests.³⁶ The first trees to colonize the newly exposed tundra-like area were spruces, followed shortly by paper birch, alder, and balsam fir.³⁷ These tree species were replaced over the succeeding millennia by more southern softwood and hardwood species, first white pine, birch, and oak, then later by hemlock and beech.³⁸ It is estimated that prior to the onset of large-scale clearing of the forests (late 1600's in Vermont and New Hampshire, and late 1700's in Maine) forests in all three states approached ninety-five percent of total land area.³⁹

The ecosystems of the Northern Forest were, therefore, dynamic and heterogeneous. Forest community transitions occurred over millennia in response to changing climates. Many animal species went extinct during this time, such as mammoths and ground sloths, probably as a result of both changing climate and overhunting by Paleo-Indians. Vegetative communities replaced one another over short spatial distances, each community was made up of several different species, and old, large individuals of all species were commonplace. Animal communities were also heterogeneous, and included several species of top-level carnivores, such as wolves, mountain lions, and wolverines.

35. HENRY D. THOREAU, *THE MAINE WOODS* 152 (Princeton Univ. Press 1972).

36. George Jacobson & Ronald Davis, *Temporary and Transitional: The Real Forest Primeval*, HABITAT: JOURNAL OF THE MAINE AUDUBON SOCIETY, reprinted in THE NORTHERN FOREST FORUM 4-5 (Spring Equinox, 1993).

37. *Id.*; Stephen T. Jackson & Donald R. Whitehead, *Holocene Vegetation Patterns in the Adirondack Mountains*, 72 *ECOLOGY* 641-653 (1991).

38. JACOBSON & DAVIS, *supra* note 36, at 4-5.

39. See John A. Litvaitis, *Responses of Early Successional Vertebrates to Historic Changes in Land Use*, 7 *CONSERVATION BIOLOGY* 866, 867 (1993) (summarizing percentages of forested land in Maine, New Hampshire, and Vermont from 1650 to present).

B. Patterns of Species Diversity

The dimension of ecological health most commonly thought of is that of the status of species. Several different species-level parameters can be evaluated.

1. Rare, Threatened, Endangered, and Extinct Species

Perhaps the most obvious measure of ecological health is the number of species officially listed as being rare, threatened, endangered, or extinct. In general, species are assigned to categories based on the number of individuals or populations recorded in recent history. Such measures are of great interest because they are inversely related to the probability that the species will persist for a given length of time. Not all species that are listed should be considered a problem for ecological health; some species are naturally uncommon, and extinction is a process that pre-dates the evolution of humans. Yet, we are not sufficiently skilled yet to know which species are rare for natural reasons. Therefore, these lists represent the minimum number of species identified by conservation professionals as being of concern and an index to the status of species-level diversity.

Each state has its own procedure for evaluating and listing such species, so comparisons among states must be made cautiously. In Vermont, species are listed as either rare, threatened, or endangered.⁴⁰ The percent of the total number of native species in each group that are listed ranges from thirteen percent (conifers) to forty-six percent (reptiles and amphibians). Furthermore, six species of animals are known to be extinct in the state (Arctic char, timber wolf, wolverine, elk, caribou, and passenger pigeon), along with eighty-eight species of plants that are known only from historical records.⁴¹

Maine created several additional categories of conservation status.⁴² To simplify analyses, I have combined the categories of Special Concern, Watch List, Indeterminate Status, and all Candidate and Nominated species into the single category of Rare. Species listed as Probably Extirpated (i.e., not seen within the last twenty years) are combined with those listed as Endangered. The

40. See *infra* Table 1.

41. *Id.*

42. See *infra* Table 2.

pattern is similar to Vermont; the percent of the total number of native species in each group that are listed ranges from six percent (conifers) to thirty-three percent (ferns and allies).

Maine also lists eleven animal species as extinct: Labrador duck, peregrine falcon, Eskimo curlew, great auk, passenger pigeon, loggerhead shrike, sea mink, timber wolf, caribou, mountain lion, and timber rattlesnake. Of the 192 plant species classified as endangered, ninety-three of them are categorized by the State of Maine as Probably Extirpated.

Like Maine, New Hampshire uses several additional categories for the status of plants. I combined species that have the status of Endangered or the rank of Critically Imperiled, Historically Known, and Believed to be Extinct under the category of Endangered. Species with the status of Threatened or the rank of Imperiled were combined under the category Threatened. Species with the rank of Very Rare or Local, Possibly in Peril, or Uncertain were categorized as Rare.⁴³ Percentages range from nineteen percent (conifers) to twenty-eight percent (flowering plants). New Hampshire lists animal species of concern only as threatened or endangered, and therefore percentages are not directly comparable to those calculated for Vermont and Maine. Extirpated species include the mountain lion, wolverine, timber wolf, caribou, and passenger pigeon, along with ten species of plants believed to be extinct and forty-three known only from historical records.⁴⁴

2. Tree Species

Available data suggest that only a few tree species are in decline. The two most notable are American chestnut and American elm, which have declined due to chestnut blight and Dutch elm disease, respectively.⁴⁵ Balsam fir has shown repeated declines as a result of cyclical peaks of spruce budworm.⁴⁶ Trends in population size for balsam fir throughout

43. See *infra* Table 3.

44. *Id.*

45. THE AUDUBON SOCIETY FIELD GUIDE TO NORTH AMERICAN TREES: EASTERN REGION 377-78, 419 (1980).

46. See DALE S. SOLOMON & THOMAS B. BRANN, U.S. DEPT OF AGRIC., TEN-YEAR IMPACT OF SPRUCE BUDWORM ON SPRUCE-FIR FORESTS OF MAINE 2-3 (Forest Service, General Technical Report NE-165 (1992)).

Maine from 1975 to 1985 showed a 57.6% decline in pure softwood stands and 30.1% in mixed woods.⁴⁷

3. Breeding Birds

Few animal taxa are used as extensively as indicators of ecosystem health as birds. Although no currently-available data set on birds is ideal for assessing long-term trends in populations, one of the best is the Breeding Bird Survey conducted throughout the country by the U.S. Fish and Wildlife Service.⁴⁸ Since 1965, established road transects in each state have been surveyed, and the number of breeding birds of each species censused.

Data are available for each species in each state in each year, and also as population trends from 1966 to 1991.⁴⁹ Trends are described in each state by plotting the average number of breeding birds of each species against year and calculating a least-squares (linear) regression. Regression equations based on fewer than fourteen transects are difficult to interpret due to small sample size. Species for which sample size is adequate are divided into three groups: no significant change in population size (i.e., the slope of the regression equation is not significantly different from zero, $P > 0.05$), significant increase in population size (the slope is significantly greater than zero, $P < 0.05$), and significant decrease in population size (the slope is significantly less than zero, $P < 0.05$). Further, to help interpret any patterns observed, I categorized each species with respect to its primary habitat type and its pattern of seasonal movement.⁵⁰

Several results emerge from these data for Maine, New Hampshire, and Vermont, but three in particular are of special interest. First, most species showed no significant change in population size when considering data during this time period.⁵¹ The percentage of species that showed no change ranged from

47. *Id.*

48. See U.S. FISH AND WILDLIFE SURVEY, OFFICE OF MIGRATORY BIRD MANAGEMENT, THE BREEDING BIRD SURVEY (1971); see also CHANDLER S. ROBBINS, ET AL., THE BREEDING BIRD SURVEY: ITS FIRST FIFTEEN YEARS 1965-1979 (U.S. Fish and Wildlife Service, Resource Publication 157 (1986)).

49. ROBBINS, et al., *supra* note 48.

50. The author is indebted to Chris Rimmer of the Vermont Institute of Natural Science, Chris Fichtel of the Vermont Department of Fish and Wildlife, and Warren King of the Otter Creek Audubon Society for improving the accuracy of these categorizations.

51. See *infra* Table 4.

fifty-five percent in Maine to thirty-seven percent in New Hampshire.

Second, some species showed significant decreases during this time, ranging from seventeen percent in Vermont to thirteen percent in New Hampshire of the state's avifauna. To assess regional-scale patterns for species declines, I determined for which species evidence existed of regional, as opposed to local, declines. To do this I excluded the species which showed declines in one state and increases or no change in another. Only seven species show region-wide declines from 1966 to 1991, and there are no obvious ecological or behavioral correlates that unite these species.⁵²

Third, almost the same can be said for species that show a region-wide increase from 1966 to 1991, with the exception that four of the six species in this group show a strong positive association with human-modified environments.⁵³ These four are among only thirteen that fall into this group in the Breeding Bird Survey data from these three states.

Assessing the status of species in the three-state region combined decreases the likelihood that population trends would indicate a change, and is thus an extremely conservative measure. A study by Witham and Hunter that looked at population trends in a subset of this region identified many more species that have changed since 1966.⁵⁴

Surprisingly, given the sampling method employed, these data seem not to be biased by the ecology of the birds. One could hypothesize that species that prefer habitats away from roads (e.g., forest interior species) would be over-represented among species with insufficient sample size, but this seems not to be the case.⁵⁵

This data set has several limitations. First, the group of species for which there is sufficient sample size is significantly biased towards perching birds ($P < 0.001$), suggesting that non-perching birds are found less often where the transects occur or

52. See *infra* Table 5.

53. See *infra* Table 6.

54. See Jack W. Witham & Malcolm L. Hunter, Jr., *Population Trends of Neotropical Migrant Landbirds in Northern Coastal New England*, in *ECOLOGY AND CONSERVATION OF NEOTROPICAL MIGRATORY LANDBIRDS* 85-95 (J.M. Hagan III and D.W. Johnston, eds., 1992).

55. See *infra* Table 7.

are less readily sampled by the techniques employed. However, neotropical migrants, the group of birds most commonly cited as being in decline in North America, are among the perching birds, so the data set appears sufficient to sample that group.

Second, the data are biased towards breeding birds. To evaluate other patterns, other data sets, such as the Christmas Bird Count, must be used.

Third, the trends are restricted to the 1966-1991 period. No earlier data are available. Also, combining these twenty-six years masks the possible existence of trends that have only recently begun. For example, if a species shows no change from 1966 to 1979 and then begins to increase or decrease; the combined data set might show no significant change, although the change is real but recent.

Fourth, species that are rare, threatened, or endangered in these states⁵⁶ do not offer sufficient sample sizes to provide trends; therefore, birds that are already of some serious conservation concern will not contribute to this data set.

4. Mammals

With the exception of game species, population trends of few mammals can be assessed. As mentioned above, several species of large carnivores and herbivores are actually or ecologically extirpated from all or part of the region, including mountain lions, lynx, timber wolves, wolverines, pine martens, caribou, and elk.⁵⁷ Some species or species groups are in decline, including all species of bats,⁵⁸ and New England cottontail and bobcat.⁵⁹ Many other species are increasing locally, including deer, moose, coyote and beaver.

Care must be taken in interpreting the ecological consequences of population declines or increases, however. The geographic distribution of New England cottontails in New Hampshire, for example, has decreased from sixty percent to twenty percent of the state. They prefer edge and successional habitats, which themselves are in decline due to a return of

56. See *infra* Tables 1-3.

57. See *infra* Table 3.

58. See Stephen C. Trombulak, *Let Not the Night Be Silent: A Natural History of Bats*, WILD EARTH 47-50 (Winter 1993-94) (reviewing the ecological situation of bats in Vermont).

59. Litvaitis, *supra* note 39.

forests following large-scale clearing during the last century. It seems probable, therefore, that New England cottontails are in large part returning to natural densities from unnaturally high levels. Also, deer are probably at population densities far in excess of what is natural. Since deer are keystone herbivores, this level will have consequences for entire plant communities. In addition, long-term monitoring programs on all other non-game species of mammals need to be established to determine the overall status of mammalian species.

5. Amphibians

Species in this group are considered to be in decline globally based on drastic population reductions and extinctions at many different locations. Data from the Northern Forest region are sparse, however. Based on their studies at Hubbard Brook in New Hampshire, Burton and Likens claimed that in the early 1970's redback salamanders were the most abundant vertebrate in the northeast.⁶⁰ Yet, studies by Andrews and Trombulak in western Vermont since 1990 have consistently failed to document such a result.⁶¹ Whether this represents a regional change or regional variation awaits further study.

6. Exotic Species

Another less appreciated dimension of species diversity in a region is the prevalence of exotic species. Exotic species, also known as introduced, alien, non-native, or non-indigenous species, are those that did not evolve in an area or immigrate to the area via non-human means. Although one might think that the introduction of exotic species would be good for biological diversity because it increases the number of species in the area, in fact, the

60. See Thomas M. Burton & Gene E. Likens, *Salamander Populations and Biomass in the Hubbard Brook Experimental Forest*, 3 COPEIA 541, 545 (1975).

61. See Stephen Trombulak & James Andrews, *Amphibian Monitoring on Mount Mansfield*, in VERMONT MONITORING COOPERATIVE: ANNUAL REPORT FOR 1992 55-67 (S.H. Wilmot & T.D. Sherbatskoy, eds., 1993); see also JAMES ANDREWS, U.S. DEP'T OF AGRIC., PRELIMINARY RESULTS OF THE INVENTORY AND MONITORING OF AMPHIBIAN BIODIVERSITY IN THE LYE BROOK WILDERNESS REGION OF THE GREEN MOUNTAIN NATIONAL FOREST (unpaginated document) (Mar.-Oct. 1993); JAMES ANDREWS, U.S. DEP'T OF AGRIC., PRELIMINARY RESULTS OF THE REPTILE AND AMPHIBIAN INVENTORY OF THE ABBEY POND AND BEAVER MEADOW REGION OF THE GREEN MOUNTAIN NATIONAL FOREST 2 (Mar.-Nov. 1993).

introduction of exotics is one of the greatest threats to biological integrity all over the world. This is because species that are native to a region are usually well-adapted to living in some kind of balance with each other. Prey species are rarely wiped out by native predators, competitors almost always have some means to ensure co-existence, and some individuals of each species usually have resistance to native diseases.

However, native species may not have the same resistance to disturbance by exotic species. The introduction of exotics has been linked to declines of biological integrity throughout the world, including the northeastern United States (for example, following the introduction of Eurasian milfoil and chestnut blight), Great Lakes (e.g., sea lamprey and zebra mussels), islands of the Caribbean (e.g., rats and mice), California rivers and lakes (e.g., exotic fishes), Hawaiian Islands (e.g., exotic plants, insects, birds, and mammals), to name only a few. In the United States alone, just seventy-nine species of exotic organisms have resulted in \$97 billion worth of harmful effects since the turn of the century.⁶²

No complete list of introduced species has been made for the Northern Forest. However, the prevalence of exotic species can be assessed for a few well-studied groups in areas that include the Northern Forest. Vascular plants are well known at the state level in northern New England. Frank Seymour's extensive synthesis of herbaria collections from New England identifies 2375 species that grow wild (i.e., outside of cultivation) in either Maine, New Hampshire, or Vermont.⁶³

Of these 2375 species, 651 of them (27.4%) were brought to the area by humans, either accidentally or on purpose.⁶⁴ The percentages vary among plant types, with far more flowering plants having been introduced (28.4%) than conifers (20%) or ferns (1.2%).⁶⁵ The percentages are similar among these three states, ranging from 26.6% in Maine to 22.7% for New Hampshire.⁶⁶ Exotic vascular plants appear to be more common

62. See U.S. CONGRESS, HARMFUL NON-INDIGENOUS SPECIES IN THE UNITED STATES 68 (Office of Technology Assessment, OTA-F-565 (1993)).

63. Figure derived from data in FRANK C. SEYMOUR, THE FLORA OF NEW ENGLAND: A MANUAL FOR THE IDENTIFICATION OF ALL VASCULAR PLANTS INCLUDING FERNS AND FERN ALLIES GROWING WITHOUT CULTIVATION IN NEW ENGLAND (2nd ed., Phytologia Memoirs V 1982).

64. See *infra* Table 8.

65. *Id.*

66. *Id.*

in northern New England in areas with greater levels of unnatural disturbance. Most exotics are described by Seymour as being found in disturbed or human-constructed habitats (e.g., roads, railroads, housing developments), suggesting that exotics are better able to invade communities when they are perturbed from their natural condition. This is supported by the observation that the overall percentage of exotics in southern New England, which has had a longer history and greater levels of disturbance than in northern New England, is over thirty percent.⁶⁷

Exotic species in other groups are also well known, including mammals (three of fifty-eight (Maine and New Hampshire) or fifty-seven (Vermont) terrestrial species are exotic),⁶⁸ birds (six of 407 breeding or wintering in Maine; six of 370 in New Hampshire; seven of 340 in Vermont),⁶⁹ and fish (five of eighty-one in Vermont).⁷⁰ Total species richness is less well known for most other groups, but they include many introduced species. Especially well documented are species that negatively-impact trees, such as gypsy moth, beech bark scale, pear thrips, red pine adelgid, hemlock woolly adelgid, balsam woolly aphid, chestnut blight, Dutch elm disease, butternut canker, European pine sawfly, and red pine scale.⁷¹

7. Gaps in Our Knowledge

Several taxa are so poorly known in this region that it is currently impossible to assess their status. These include, but are not limited to:

(a) Soil flora and fauna. This group is only beginning to be assessed anywhere in temperate forest ecosystems, let alone at representative sites throughout a region. Given the importance of the soil biota in nutrient cycling,

67. See *infra* Table 8.

68. Figure derived from data in A.J. GODIN, *WILD MAMMALS OF NEW ENGLAND* (1977).

69. Figure derived from data in D. DESANTE & P. PYLE, *DISTRIBUTIONAL CHECKLIST OF NORTH AMERICAN BIRDS* (1976).

70. Fish statistics based on a checklist developed by Stephen C. Trombulak compiled from various sources (on file with the author).

71. See UNITED STATES FOREST SERV., U.S. DEP'T OF AGRIC., *A GUIDE TO COMMON INSECTS AND DISEASES OF FOREST TREES IN THE NORTHEASTERN UNITED STATES* 5, 40, 44, 46, 54, 64, 71 (1976); U.S. DEP'T OF AGRIC., *NORTHEASTERN AREA FOREST HEALTH REPORT* 7-8, 13, 15, 29 (1993).

decomposition, and succession, research on this group is a high priority.

(b) Insects. Apart from isolated insect surveys, the status of insect populations is known for few species other than those of economic importance, such as spruce budworm.⁷²

(c) Fungi. The recent fifty percent decline of fungi in forested ecosystems in Europe raise the troubling possibility of a similar event here.⁷³

(d) Lichens.

(e) All aquatic organisms.

C. Patterns of Genetic Diversity

This is the hardest level of ecological health to assess because it is not amenable to easy inventory and monitoring programs. Further, few baseline data exist for any species, making it difficult to determine what current values of genetic diversity mean.

Genetic diversity is decreased in nature when populations are reduced in size or subjected to artificial selection. Russell Lande has suggested that species at low population densities are at greater demographic risk (e.g., accidental death of the entire population in a single chance event) than genetic risk (e.g., death from an epidemic due to loss of genetic resistance).⁷⁴ If true, genetic diversity in small populations, such as rare, threatened, or endangered species, is of secondary concern.

Genetic diversity in species subject to intense artificial selection ought to be of great concern, however. Population sizes could be quite large, yet the species could be at great risk of

72. See generally DALE S. SOLOMON & THOMAS B. BRANN, U.S. DEPT OF AGRIC., TEN-YEAR IMPACT OF SPRUCE BUDWORM ON SPRUCE-FIR FORESTS OF MAINE (Forest Service, General Technical Report NE-165) (1992) (discussing the effect of spruce budworm in the spruce-fir region of Maine).

73. John Jaenike, *Mass Extinction of European Fungi*, 6 TRENDS IN ECOLOGY AND EVOLUTION 174-75 (1991).

74. See Russell Lande, *Genetics and Demography in Biological Conservation*, 241 SCIENCE 1455-60 (Sept. 1988).

extirpation. Whether artificial selection has been intense enough for any species in this region, however, is another matter. Studies of fourteen species of hardwood trees, summarized by Li, et al., documented total genetic diversity values from between 0.05 (eastern cottonwood) to 0.24 (trembling aspen). Intensively managed species, such as sugar maples, have genetic diversity values well within this range, suggesting that modification of the genome of these species has not yet occurred.⁷⁵

Candidate species that deserve immediate attention include fish raised exclusively in hatcheries, species subject to hunting or fishing (especially those with size limits), and plant species that experience breeding or selection programs as part of large-scale commercial operations.⁷⁶

D. Patterns of Ecosystem Diversity and Condition

1. Forest Ecosystems

Conditions in forested ecosystems can be discussed in two general subcategories: tree and non-tree communities. Several different parameters can be used to assess the general condition of the trees, including the total amount of forested area, size and age classes of trees, and overall tree health. Each of these can in turn be evaluated in three general time frames: present in comparison to baseline conditions, long-term trends, and short-term trends.

In all three states, the total amount of forested area is less than it was prior to European settlement.⁷⁷ Various estimates place the baseline percent of forested area at approximately ninety-five in all three states. Currently, estimates are eighty-nine percent, eighty-seven percent, and seventy-seven percent for

75. See Peng Li, John MacKay, & Jean Bousquet, *Genetic Diversity in Canadian Hardwoods: Implications for Conservation*, 68 THE FORESTRY CHRONICLE 709, 714 (Dec. 1992).

76. See Y.A. El-Kassaby, *Domestication and Genetic Diversity—Should We Be Concerned?* 68 THE FORESTRY CHRONICLE 687-700 (1992).

77. See *infra* Figure 1.

Maine (1982), New Hampshire (1983), and Vermont (1983), respectively.⁷⁸

Over the past one hundred years, forested area has increased from historical lows.⁷⁹ This has generated a positive trend in this parameter of ecological health. Long-term trends (1952-1987), however, indicate that the forested area has changed little in the past forty years.⁸⁰ Short-term trends have also shown either slight increases or decreases.⁸¹ This suggests that the long-term trends are approaching a plateau and that baseline conditions will not be reached in the near future.

Forest area can also be assessed by forest community type. Since European settlement, forest composition has probably changed to some extent. In general, species such as red spruce and American beech have probably decreased and aspen, red maple, and sugar maple have probably increased.⁸²

Short-term trends are also of interest. In general, oak/hickory and northern hardwoods groups increased in Vermont while other forest types declined; white/red pine and oak/hickory forests declined in New Hampshire while other forest types increased; and in Maine, spruce/fir, loblolly/shortleaf, and elm/ash/red maple groups declined while all others increased.⁸³ The only trend found in all three states is the increase in northern hardwoods.

Similar analyses should be conducted for long-term trends as well, incorporating data from the most recent decade as they are published.

Size and age class structure of trees have also changed dramatically over time. Compared to baseline conditions, there has been a very large decrease in the amount of old-aged and very large trees. Forests where such trees predominate are commonly referred to as old growth. Although occasionally discussed as an

78. DOUGLAS S. POWELL & DAVID R. DICKSON, U.S. DEP'T OF AGRIC., FOREST STATISTICS FOR MAINE: 1971 AND 1982 9 (1984); THOMAS S. FRIESWYK & ANNE M. MALLEY, U.S. DEP'T OF AGRIC., FOREST STATISTICS FOR NEW HAMPSHIRE: 1973 AND 1983 (1985); THOMAS S. FRIESWYK & ANNE M. MALLEY, U.S. DEP'T OF AGRICULTURE, FOREST STATISTICS FOR VERMONT: 1973 AND 1983 1, 11 (1985).

79. See *infra* Figure 1.

80. See KAREN L. WADDELL, ET AL., U.S. DEP'T OF AGRIC., FOREST STATISTICS OF THE UNITED STATES 12-13, 21 (1989).

81. See *infra* Table 9.

82. David Publicover, *Forest Transitions*, in PROCEEDINGS OF THE FIRST CONFERENCE ON THE ECOLOGY OF THE NORTHERN FOREST 44 (Aug. 1993).

83. See *infra* Table 9.

ecosystem type of its own, it is more properly considered an age-size class of forest ecosystems in general.

Old growth is a general term which describes stands of forest characterized by (a) older age classes of dominant tree species, and (b) a lack of human-caused mortality, either by cutting or fire. The age at which a stand becomes old growth is therefore based on the biology of the species under the conditions where it is growing. For example, balsam fir growing near treeline might under natural conditions only be expected to reach one hundred years old before dying, whereas eastern hemlocks at lower elevations may easily live to be more than 400 years old. Old-growth forests are not delineated based on tree size; trees growing near treeline might only reach five or six feet in height despite being many decades old. Yet old trees of most species reach very large sizes, both in height and girth, and old growth forest in general provide different physical environments than do younger forests.

The distribution of old growth forests prior to European colonization is only speculative, but it is reasonable to assume that the distribution was extensive and limited only by the patterns of natural disturbances that moved through an area, such as fire and storms. Craig Lorimer demonstrated that forests in central Maine were subjected to fire approximately once every 800 years and devastating storms approximately once every 1000 years.⁸⁴ This suggests that even in the face of natural patterns of disturbance, trees throughout this region had the opportunity to reach great age. It has been suggested that seventy-five percent or more of the pre-settlement forests in Wisconsin, similar to those of the Northern Forest region, were in an old-growth condition at any given time.⁸⁵

American Indians were probably not a major force altering the age structure of the forest in this region. The native population of the Northern Forest prior to European colonization probably numbered no more than 20,000 and was primarily a hunter-gatherer society.⁸⁶ Therefore, trees would rarely need to be cut or burned, and never over extensive areas. (This is

84. Craig G. Lorimer, *The Presettlement Forest and Natural Disturbance Cycle of Northeastern Maine*, 58 *ECOLOGY* 139, 145-46 (1977).

85. Charles D. Canham & Ori L. Loucks, *Catastrophic Windthrow of the Presettlement Forests of Wisconsin*, 65 *ECOLOGY* 803, 807 (1984).

86. See Trombulak, *supra* note 32, at 14.

contrasted sharply with American Indians in southern New England, who were primarily agriculturists and cleared extensive acreage for crops and firewood.)⁸⁷

The most complete inventory of old growth stands in the Northern Forest indicates that current old growth of all types make up less than 0.5% (five in every 1000 acres) of region.⁸⁸ Furthermore, the majority of these stands are small in size;⁸⁹ the median size of the stands is only 200 acres (less than 1/3 square mile), and one stand at the Southern Five Ponds Wilderness Area in the Adirondack Park alone is thirty-eight percent of the total for the entire Northern Forest.⁹⁰ Although Mary Davis acknowledges that this inventory is not complete because of a general lack of knowledge of land-use history in many remote and high-elevation regions, especially in New York, it is almost certainly accurate to within an order of magnitude and likely does not exclude any large tracts. Although I agree with her call for more extensive surveys of old growth, I doubt if additional work will change our overall understanding of old growth in this region.

Old growth is a very small fraction of the forests in this region today, never exceeding more than 1.3% (New Hampshire).⁹¹ There is virtually no old growth in the Northern Forest of Vermont. The largest of the three stands is only 150 acres (< 1/4 square mile) in size.⁹²

Further, the old growth that does exist is not equitably distributed among forest types. In Maine, for example, the old growth is heavily biased towards balsam fir forests (sixty-six percent of the total old-growth area for that state, fifteen of fifty-one stands, while balsam fir made up only 6.5% of timberland area in 1982), indicating that existing stands of old growth do not represent native ecosystems across their natural range of abundance and distribution.⁹³ This bias is probably related to their predominance at higher elevations, which have made them less accessible to harvesting.

87. CRONON, *supra* note 34.

88. MARY B. DAVIS, OLD GROWTH IN THE EAST, A SURVEY (1993). *See infra* Table 10.

89. *See infra* Figure 2.

90. DAVIS, *supra* note 88.

91. *See infra* Table 10.

92. DAVIS, *supra* note 88.

93. POWELL & DICKSON, *supra* note 78.

It is clear, therefore, that old growth, as a condition of forested ecosystems, is greatly reduced from its natural distribution and abundance. What is less obvious is what further consequences this has for the ecological health of the region. Surveys for old-growth dependent species of beetles and lichens have been conducted in only a few places in the Northern Forest region, and these have consistently demonstrated the existence of species present in old growth but not secondary forests.⁹⁴ Further surveys for other groups of organisms have not been conducted as they have in other northern temperate forests, a situation that is in serious need of correction.⁹⁵

Recent short-term trends in forest community types indicate an increase in the average size of trees. In Vermont, there was a 12.8% increase from 1973 to 1983 in the volume of growing-stock trees of all softwood species combined. This increase was due solely to increases in trees greater than nine inches diameter at breast height ("dbh"), since the volume of softwoods less than this size decreased by almost 2.0%.⁹⁶ All hardwoods combined showed a 32.3% increase during this same period, with increases in each size class. A similar pattern is seen for sawtimber trees as well.⁹⁷

This pattern was repeated in both New Hampshire and Maine. In New Hampshire, there was a 1.5% increase from 1973 to 1983 in the volume of growing-stock trees of all softwood

94. Donald S. Chandler, *Species Richness and Abundance of Pselaphidae (Coleoptera) in Old-Growth and 40-year-old Forests in New Hampshire*, 65 CANADIAN JOURNAL OF ZOOLOGY 608-15 (1987); Donald S. Chandler, *Comparison of Some Slime-Mold and Fungus Feeding Beetles (Coleoptera: Eucinetoidea, Cucujoidea) in an Old-Growth and 40-year-old Forest in New Hampshire*, 45(3) THE COLEOPTERISTS BULLETIN 239-56 (1991); Donald S. Chandler & Stewart B. Peck, *Diversity and Seasonality of Leiodid Beetles (Coleoptera: Leiodidae) in an Old-Growth and 40-year-old Forest in New Hampshire*, 21(6) ENVTL. ENTOMOLOGY 1283-93 (Dec. 1992).

95. Andrew B. Carey, *Wildlife Associated with Old-Growth Forests in the Pacific Northwest*, 9 NATURAL AREAS JOURNAL 151-162 (1989); John D. Lattin, *Arthropod Diversity in Northwest Old-Growth Forests*, WINGS 7-10 (Summer 1990); A. Moldenke & J.D. Lattin, *Dispersal Characteristics of Old-Growth Soil Arthropods: The Potential Loss of Diversity and Biological Function*, 6 NORTHWEST ENVTL. J. 408-409 (1990); Steven B. Selva, *Lichen Diversity and Stand Continuity in the Northern Hardwoods and Spruce-Fir Forests of Northern New England and Western New Brunswick*, 97(4) THE BRYOLOGIST 424-29 (Winter 1994).

96. Percentage derived from Tables 28 and 29 in THOMAS S. FRIESWYK & ANNE M. MALLEY, U.S. DEP'T OF AGRIC., FOREST STATISTICS FOR VERMONT: 1973 AND 1983 at 32-33 (1985).

97. *Id.*

species combined, due solely to increases in trees greater than eleven inches dbh.⁹⁸ All hardwoods combined showed a 30.1% increase during this same period, with increases in most size classes, including all above fifteen inches dbh.⁹⁹ In Maine, the increase from 1971 to 1982 in the volume of growing-stock trees of all softwood species combined was 1.4%, with the increase due to trees greater than nine inches dbh.¹⁰⁰ Hardwoods increased by eighteen percent with increases in all size classes except fifteen to seventeen inches dbh.¹⁰¹ Relative to baseline conditions, however, the largest size class (greater than twenty-nine inches dbh), which comprised no more than 1.1% of all growing-stock trees in 1983, is still much less than in typical old-growth forests.¹⁰²

Age-class condition can also be evaluated at the stand level. In other words, what is the percentage of forests that are in even-aged stands? Presumably, under natural conditions, when fire, storms, or insect damage caused major mortality at a site, the first trees to colonize the area would all be of the same age. However, under most natural conditions younger age classes of trees grow up in the understory, resulting in a general mixed-age composition. Unfortunately, these data are not currently readily available. Measurements of this parameter would be important for further assessment of forest condition.

Tree size and age are themselves a function of past patterns of mortality. Looking at tree health and mortality in the present also provides an indication of future forest conditions. Several forest stressors exert an influence on trees in this region: disease, herbivory, air pollution, forest harvesting, and climate. A detailed analysis of all of these factors is beyond the scope of this paper, but a few general trends can be described.

First, despite extensive research, acid deposition and atmospheric pollution have not been shown to be causally linked

98. Percentage derived from Tables 28 and 29 in THOMAS S. FRIESWYK & ANNE M. MALLEY, U.S. DEPT OF AGRIC., FOREST STATISTICS FOR NEW HAMPSHIRE: 1973 AND 1983 at 32-33 (1985).

99. *Id.*

100. Percentage derived from Tables 27 and 28 in DOUGLAS S. POWELL & DAVID R. DICKSON, U.S. DEPT OF AGRIC., FOREST STATISTICS FOR MAINE: 1971 AND 1982 at 30-31 (1984).

101. *Id.*

102. Compare Tables 27 and 28 in POWELL & DICKSON, *supra* note 100 with descriptions of tree size by CRONON, *supra* note 34.

with regional patterns of forest decline, except probably for high-elevation red spruce.¹⁰³ Second, recent assessments of tree health throughout the region indicate that every species present either has had or is likely to have a serious mortality event, primarily associated with some disease or pest organism.¹⁰⁴ Despite this prediction, however, tree health in Vermont generally improved between 1985 to 1991.¹⁰⁵

Conditions of non-tree species in forest ecosystems have been less well documented than those of tree species. Apart from the species discussed earlier that have declined or been extirpated, our understanding of conditions in this aspect of forests is characterized more by what we don't know than what we do. Studies such as Duffy and Meier's on understory plants in the southern Appalachian Mountains are desperately needed in this region.¹⁰⁶

2. Aquatic Ecosystems

As with their terrestrial counterparts, aquatic ecosystems can be evaluated in numerous ways. Perhaps the easiest is the designation each state gives its waterways under Section 305(b) of the Federal Water Pollution Control Act¹⁰⁷ with respect to its ability to support its "designated uses," which covers the support of aquatic organisms, drinking supply, and agriculture. Although each state varies with respect to how the data are generated, especially the percent of the waters that are actually monitored, they are broadly comparable.¹⁰⁸

103. See MARGARET MILLER-WEEKS & DEAN SMORONK, U.S. DEPT OF AGRIC., AERIAL ASSESSMENT OF RED SPRUCE AND BALSAM FIR CONDITION IN THE ADIRONDACK REGION OF NEW YORK, THE GREEN MOUNTAINS OF VERMONT, THE WHITE MOUNTAINS OF NEW HAMPSHIRE, AND THE MOUNTAINS OF WESTERN MAINE 1985-1986 12, 18, 20 (date unavailable).

104. SOLOMON & BRANN, *supra* note 72.

105. See RONALD KELLEY ET AL., VERMONT AGENCY FOR NATURAL RESOURCES, DEPT OF FORESTS, PARKS, & RECREATION, VERMONT HARDWOOD TREE HEALTH IN 1991 COMPARED TO 1986 16 (1992).

106. David C. Duffy & Albert J. Meier, *Do Appalachian Herbaceous Understories Ever Recover from Clearcutting?* 6 CONSERVATION BIOLOGY 196-201 (June 1992).

107. Federal Water Pollution Control Act of 1977, 33 U.S.C. §§ 1251-1387 (Supp. V 1993).

108. See *infra* Table 11.

In Maine, the number of miles of rivers that do not fully support their designated uses is 394.¹⁰⁹ Causes for this designation include fish consumption advisories, toxics, pathogens, and direct fish kills. Comparisons to previous years cannot be made, however, because of changes by the state in how rivers affected with dioxin are reported. Over twenty-four percent (233,719 acres) of the lake area is only partially supporting of uses (due primarily to nutrient loading, siltation, and toxics), and 160 square miles are not fully supporting of shellfish beds. Maine has also lost about twenty percent of its wetlands since colonial times, or 1,260,817 acres.¹¹⁰ Causes of wetland loss have been development, road construction, pollution, and agriculture.

In Vermont, a similar pattern is seen.¹¹¹ Almost forty-one percent (2152 miles) of the assessed rivers and streams did not fully support their uses, due primarily to pollution, siltation, and habitat alteration.¹¹² The same is true for sixty-three percent (33,498 acres) of lakes and ponds (nutrients, siltation, habitat alteration, and exotic plants) and one hundred percent (174,175 acres) of Lake Champlain (nutrients, algae, and siltation).¹¹³ Estimates of wetland loss have not been made over long time-frames, but was calculated to be extremely small (eighty-two acres of 220,000 in the state) in 1990. However, this estimate is based on a small sampling of 530 development projects that year.¹¹⁴

Less detail was available for New Hampshire, but similar trends are seen.¹¹⁵ Two hundred-seventeen miles of rivers do not fully support their designated uses, along with 23,037 acres of lakes and ponds, and 18.4 square miles of estuaries.

109. *Id.*

110. MAINE DEPT OF ENVTL. PROTECTION, BUREAU OF LAND & WATER CONTROL, STATE OF MAINE 1994 WATER QUALITY ASSESSMENT—A REPORT TO CONGRESS PREPARED PURSUANT TO SECTION 305(B) OF THE FEDERAL WATER POLLUTION CONTROL ACT AS AMENDED 61 (1994) [hereinafter MAINE DEP].

111. *See infra* Table 11.

112. *Id.*

113. Values derived from Tables 4a and 4b in VERMONT DEPT OF ENVTL. CONSERVATION, STATE OF VERMONT—1992 WATER QUALITY ASSESSMENT 305(B) REPORT at 15-16 (1992).

114. Values derived from Table 12 in VERMONT DEPT OF ENVTL. CONSERVATION, STATE OF VERMONT—1992 WATER QUALITY ASSESSMENT 305(B) REPORT at 40 (1992).

115. *See infra* Table 11.

E. Patterns of Health in Ecosystem Function

Few ecosystem functions have been sufficiently well-documented for baseline patterns to be established. We have, perhaps, the greatest information on regional disturbance regimes. Disturbance comes in four general categories: fire, pests, ice and snow, and wind. As noted above, fire occurred infrequently in a given location, perhaps as rarely as once every 800 years in northcentral Maine. Even if fires occurred more frequently in other, drier locations, it is highly likely that the frequency of fire has increased greatly during the last 200 years. Since plant communities are often well adapted to fire regimes, and the presence of individual species can be altered by changes in fire frequency and intensity, additional work on pre- and post-settlement fire regimes is urgently needed.

Also, the prevalence of pests was noted above.¹¹⁶ It is certain that the introduction of numerous exotic pests in the last century has led to an increase in disturbance due to pest-induced mortality. It is also possible that the frequency of mortality events caused by native pests, such as spruce budworm, has increased recently due to anthropogenic increases in the proportion of balsam fir.

Wind, ice, and snow also cause mortality, opening up the forest canopy. However, there is no evidence that the frequency or severity of these mortality agents has changed over time.

Other aspects of ecosystem function are much less well documented or understood at the regional level. It is necessary to conduct long-term studies throughout this area to assess patterns of carbon fixation, nutrient cycling, and soil formation.

CONCLUSION

These data indicate several important features about ecological health in the Northern Forest. The first is that ecological health must be assessed by considering more than just traditional indices of biological diversity, such as the number of species in an area. Ecological conditions cannot be adequately evaluated without looking at levels of genetic, species, and

116. SOLOMON & BRANN, *supra* note 72.

ecosystem diversity compared to natural conditions, and the processes that connect components within and among these levels.

The second feature is that no single parameter alone is a sufficient indicator of ecological conditions. Although it is time consuming and expensive to assess the status of several different parameters, to do otherwise is to risk missing important changes in natural conditions, changes which might have serious implications for the long-term maintenance of biological integrity.

The data sets reviewed here, which I admit are only a subset of a full description of conditions in the region, indicate that for many taxonomic groups, a large percent of species (defined as ten percent or more) exist at population sizes that put them at serious risk of extinction in a short period of time. Other taxonomic groups, like birds and conifers, appear to be less at risk. Still other taxonomic groups are so poorly known that data are not yet available to assess their status. Most notable here are soil-dwelling microbes, fungi, insects, and most aquatic species. It is particularly troubling that these groups are so poorly known since as ecological guilds they play important roles in many ecosystem processes, such as nutrient cycling and herbivory. Still other taxonomic groups have a very high incidence of local extinction. This is particularly true of the large mammalian carnivores, whose removal from this region have eliminated their important contribution to the regulation of herbivores.

Additionally, the species richness of many taxonomic groups has been noticeably altered by the introduction of exotic species. The number of exotic species is quite high for vascular plants, but low for most groups of animals.

Even a parameter as narrowly proscribed as "the condition of tree communities" requires several different measures to be accurately described. The amount of forest land and the number of standing trees is probably close to natural levels. Although recent trends are in the direction of improved ecological health, the average size of trees is still much lower than natural, which is probably a function of the decrease in the average age of the forests and the extremely small fraction (0.5%) of the forests that are old growth. Many other parameters of ecological health are very poorly studied; genetic diversity, carbon flux, and nutrient cycling are among the most critical.

The power of an assessment of ecological health to assist in policy analyses is easily seen by its use in testing claims about the merit of particular social conditions. For example, Canham

makes the case that a laissez-faire system of private owners is advantageous for "biodiversity" (which he leaves undefined).¹¹⁷ This statement can be treated as an hypothesis amenable to testing.

Current conditions in Vermont might provide such a test. In the Northern Forest region of Vermont ninety-five percent of the land is private, and eighty-five percent of that is in small, non-industrial ownership.¹¹⁸ The analyses presented in this chapter document that this pattern of ownership has resulted in 0.01% of the forest land being retained as old growth, between thirteen percent (conifers) and forty-six percent (reptiles and amphibians) of the well-inventoried taxa being listed as rare, threatened, or endangered, six animal species known to be extinct, eighty-eight percent plant species possibly extinct, 26.3% of the total flora exotic, and forty-one percent and sixty-three percent of the rivers and lakes, respectively, not fully supporting their uses.¹¹⁹ Armed with this information, society is then in a position to assess the validity of Canham's hypothesis.

It ought to be clear that a focus on ecological health in any policy process, especially the one associated with the Northern Forest, needs to focus on ecosystem health as a real indicator of how we are doing as a society. If we automatically decide that it is a red herring, perhaps because we feel socio-economic issues are more important, then we stand an excellent chance of losing the very biological base that allows us to follow our cultural traditions. If we automatically assume that all human activity has resulted in an ecological catastrophe, then we will inevitably foster a climate where it is impossible to solve the real problems. The ecological health of the Northern Forest is not, and cannot be, all good or all bad. The wisest course of action we as a society can take is to maintain an inventory and monitoring program that spans the full spectrum of related parameters, celebrate our successes, acknowledge our failures, and implement a comprehensive conservation strategy designed to restore and protect biological integrity throughout the region.

117. Canham, *supra* note 17.

118. NFLS, *supra* note 1.

119. See *supra* notes 40-73 and accompanying text.

Table 1. Number of species listed as rare, threatened, or endangered in Vermont.¹²⁰

| | Rare ^a | Threatened | Endangered | Total |
|-------------------------|-------------------|------------|------------|-----------|
| Mosses | 0 | 0 | 2 | 2 |
| Ferns and allies | 23 | 7 | 3 | 33(0.43) |
| Conifers | 0 | 2 | 0 | 2(0.13) |
| Flowering Plants | 345 | 85 | 56 | 486(0.36) |
| Invertebrates | 106 | 6 | 3 | 115 |
| Fish | 21 | 2 | 3 | 26(0.34) |
| Reptiles/ Amphibians | 12 | 2 | 3 | 17(0.46) |
| Birds | 45 | 3 | 8 | 56(0.17) |
| Mammals | 11 | 1 | 3 | 15(0.28) |

^a Includes species of special concern and species that are missing and not seen within the last twenty-five years.

120. See VERMONT NONGAME AND NATURAL HERITAGE PROGRAM, DEP'T OF FISH AND WILDLIFE, RARE AND UNCOMMON PLANTS OF VERMONT (July 1993); VERMONT NONGAME AND NATURAL HERITAGE PROGRAM, DEP'T OF FISH AND WILDLIFE, RARE AND UNCOMMON ANIMALS OF VERMONT (July 1993); *Endangered Species News*, NATURAL HERITAGE HARMONIES (Publication of the Nongame and Natural Heritage Program of the Dep't of Fish and Wildlife, Vermont Agency of Natural Resources), Dec. 1994, at 5. Values in parentheses following some of the totals are the proportion of the known native flora or fauna. R.M. DEGRAAF & D.D. RUDIS, AMPHIBIANS AND REPTILES OF NEW ENGLAND (1983). See *supra* notes 40-73 and accompanying text.

Table 2. Number of species listed as rare, threatened, or endangered in Maine (excluding marine reptiles and mammals).¹²¹

| | Rare ^a | Threatened | Endangered ^b | Total |
|----------------------|-------------------|------------|-------------------------|-----------|
| Ferns and allies | 7 | 6 | 10 | 23(0.33) |
| Conifers | 0 | 1 | 0 | 1(0.06) |
| Flowering Plants | 86 | 69 | 182 | 337(0.25) |
| Fish | 4 | 0 | 0 | 4 |
| Reptiles\ Amphibians | 4 | 2 | 2 | 8(0.23) |
| Birds | 39 | 1 | 8 | 48(0.12) |
| Mammals | 13 | 1 | 0 | 14(0.25) |

^a Includes species that are recorded as Special Concern, Watch List, Indeterminate Status, Candidate, and Nominated Species.

^b Includes species that are listed as Probably Extirpated.

121. MAINE NATURAL AREAS PROGRAM, DEP'T OF ECON. AND COMMUNITY DEV., ELEMENTS OF NATURAL DIVERSITY—RARE, THREATENED AND ENDANGERED PLANTS (1994); STATE OF MAINE, THE OFFICIAL WHO'S WHO OF RARE AND ENDANGERED WILDLIFE IN MAINE (date unavailable). Values in parentheses following some of the totals are the proportion of the known native flora or fauna. See *supra* Table 1.

Table 3. Number of species listed as rare, threatened, or endangered in New Hampshire.¹²²

| | Rare ^a | Threatened ^b | Endangered ^c | Total |
|-------------------------|-------------------|-------------------------|-------------------------|-----------|
| Ferns and allies | 0 | 10 | 8 | 18(0.025) |
| Conifers | 0 | 2 | 1 | 3(0.19) |
| Flowering Plants | 28 | 154 | 186 | 368(0.28) |
| Invertebrates | — | 3 | 6 | 9 |
| Fish | — | 0 | 2 | 2 |
| Reptiles\ Amphibians | — | 0 | 1 | 1(0.03) |
| Birds | — | 9 | 10 | 19(0.05) |
| Mammals | — | 1 | 2 | 3(0.05) |

- ^a Information is only available for plants. Combines species with the rank of Very Rare or Local (S3), Possibly in Peril (SU), or Uncertain (S?).
- ^b Combines species that have the status of Threatened (ST) or, if no status code is assigned, the rank of Imperiled (S2).
- ^c Combines species that have the status of Endangered (SE) or, if no status code is assigned, the rank of Critically Imperiled (S1), Historically Known (SH), and Believed to be Extinct (SX).

122. STATE OF N.H., DEPT OF RESOURCES AND ECON. DEV., NEW HAMPSHIRE NATURAL HERITAGE INVENTORY PLANT TRACKING LIST (July 1994); NEW HAMPSHIRE FISH AND GAME DEPT, NONGAME AND ENDANGERED WILDLIFE PROGRAM, ENDANGERED AND THREATENED WILDLIFE OF NEW HAMPSHIRE (Jan. 1992). Values in parentheses following the totals are the proportion of the known native fauna. See *supra* Table 1.

Table 4. Population trends for birds in Maine, New Hampshire, and Vermont from 1966 to 1991.¹²³

| Status | Maine | New Hampshire | Vermont |
|-------------------|----------|---------------|----------|
| Insufficient Data | 34(0.21) | 55(0.36) | 48(0.32) |
| No Change | 88(0.55) | 57(0.37) | 65(0.44) |
| Increase | 14(0.09) | 21(0.14) | 11(0.07) |
| Decrease | 23(0.15) | 20(0.13) | 25(0.17) |
| Total | 159 | 153 | 149 |

123. Values indicate the number of species demonstrative of each population trend, with the proportion of the state total in parentheses. Species recorded on fewer than fourteen of the transects in a state do not provide sufficient data to assess their trends in that state. Data for other species are fitted to a regression line, and the slope of the line is either significantly increasing (greater than 0.0; $P < 0.05$), significantly decreasing (less than 0.0; $P < 0.05$), or not changing (not significantly different from 0.0; $P > 0.05$). The total number of species listed in each state may not equal the total number of birds known to breed in that state if species were not recorded on any transect.

Table 5. Species recording in the Breeding Bird Survey whose population trends from 1966-1991 showed a significant ($P < 0.05$) decrease in one of the three northern New England states, and whose trend in each of the other two states is either also a significant decrease (D), a sample size too small ($n < 14$) to draw conclusions (NS), or is not present on any transect (NA).

| Species | Habitat | Seasonal Movement | M E | N H | V T |
|-------------------------|--|----------------------------------|--------|--------|--------|
| Great Black-backed Gull | Standing water | East-West in New England | D | N S | N A |
| Yellow-Shafted Flicker | Deciduous forest; second growth, edges, and openings | North-South in the United States | D | D | D |
| Swainson's Thrush | Coniferous and mixed forest; forest interior and second growth | Neotropical | D | N S | N S |
| Field Sparrow | Scrub | North-South in the United States | D | D | D |
| Song Sparrow | Scrub | North-South in the United States | D | D | D |
| White-Throated Sparrow | Forest edge and high-elevation spruce-fir forests | North-South in the United States | D | D | D |
| Slate-Coloured Junco | Coniferous and mixed forest; subalpine forest; second growth and edges | North-South in the United States | D | D | D |

Table 6. Species recording in the Breeding Bird Survey whose population trends from 1966-1991 showed a significant ($P < 0.05$) increase in one of the three northern New England states, and whose trend in each of the other two states is either also a significant increase (I) or the sample size was too small ($n < 14$) to draw conclusions (NS).

| Species | Habitat | Seasonal Movement | M E | N H | V T |
|-----------------------|---|----------------------------------|--------|--------|--------|
| Mourning Dove | Human-modified | North-South in the United States | I | I | I |
| Purple Martin | Human-modified | Neotropical | I | N S | N S |
| Tufted Titmouse | Deciduous; second growth; edge and openings | Permanent | N S | I | N S |
| Northern Mocking Bird | Human-modified | Permanent | I | I | I |
| Pine Warbler | Coniferous; forest interior | North-South in the United States | I | I | N S |
| House Finch | Human-modified | North-South in the United States | I | I | I |

Table 7. Predominant habitat preferences of species for which there was insufficient data (recorded on fewer than 14 transects) to assess population trends. Few species are restricted to only one habitat type, so assignments were made based on the most common or likely habitat for each species.

| Habitat | Maine | New Hampshire | Vermont |
|-----------------|---------|---------------|---------|
| Human-modified | 1(15) | 1(15) | 1(15) |
| Open Field | 7(20) | 8(18) | 12(23) |
| Water | 11(27) | 12(22) | 9(19) |
| Scrub | 4(18) | 7(19) | 5(17) |
| Forest Interior | 8(42) | 13(39) | 10(36) |
| Second Growth | 2(28) | 11(31) | 9(30) |
| Edge | 1(9) | 3(9) | 2(9) |
| Total | 34(159) | 55(153) | 48(149) |

Table 8. The number of native and exotic vascular plants grown outside of cultivation in the northern New England states.¹²⁴

| Region | Ferns | | Conifers | | Angiosperms | | All Species | |
|---------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | N ¹ | E ² |
| Maine | 70 | 1 | 16 | 4 | 1363 | 521 | 1449 | 526 |
| New Hampshire | 72 | 0 | 16 | 3 | 1309 | 408 | 1397 | 411 |
| Vermont | 77 | 0 | 15 | 3 | 1333 | 506 | 1425 | 509 |
| Total | 80 | 1 | 16 | 4 | 1628 | 646 | 1724 | 651 |

¹ Native

² Exotic

124. SEYMOUR, *supra* note 63.

Table 9. Percent change in the total area for each community type and all forested areas.¹²⁵

| Forest Community Type | Maine | New Hampshire | Vermont |
|--------------------------|--------|---------------|---------|
| White/Red Pine Group | 15.2% | -10.3% | -7.5% |
| Spruce/Fir Group | -7.3% | 11.5% | -5.8% |
| Hard Pine Group | — | 35.0% | — |
| Loblolly/Shortleaf Group | -39.4% | — | — |
| Oak/Pine Group | 37.1% | 117.6% | -16.1% |
| Oak/Hickory Group | 13.1% | -5.5% | 19.9% |
| Elm/Ash/Red Maple Group | -30.9% | 39.2% | -4.5% |
| Northern Hardwoods Group | 2.3% | 9.8% | 3.6% |
| Aspen/Birch Group | 55.2% | 2.3% | -14.6% |
| Total | 1.0% | 2.6% | -0.2% |

125. Data derived from sources cited *supra* note 78.

Table 10. The amount of old growth in the Northern Forest.¹²⁶

| State | Total NF Acreage | Old Growth Acreage | % of Total | # of Stands |
|---------------|------------------|--------------------|------------|-------------|
| Maine | 15,000,000 | 32,332 | 0.22% | 51 |
| New Hampshire | 1,200,000 | 15,287 | 1.27% | 6 |
| Vermont | 2,000,000 | 287 | 0.01% | 3 |
| New York | 7,600,000 | 79,540 | 1.05% | 27 |
| Total | 25,800,000 | 127,446 | 0.49% | 87 |

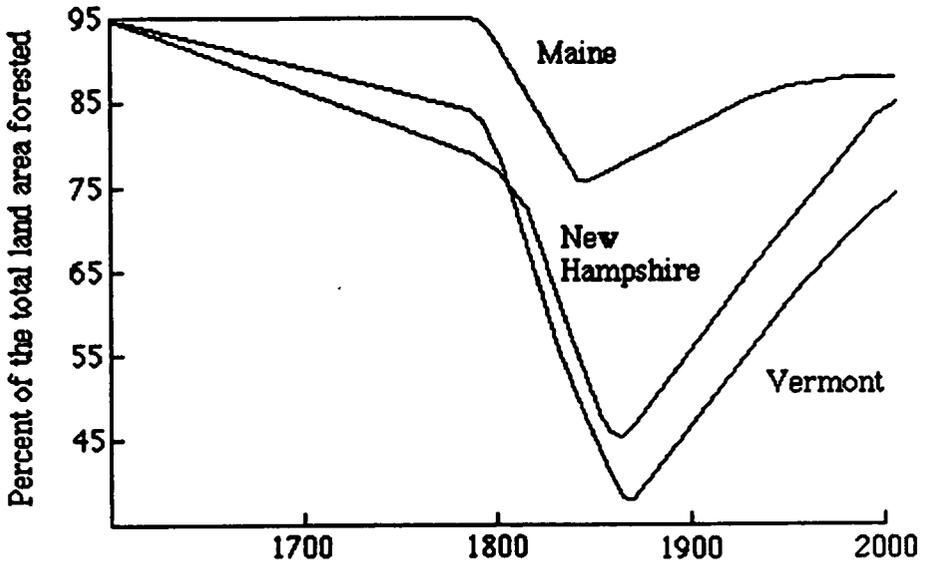
126. DAVIS, *supra* note 88. Although Davis' survey is the most complete inventory available, she notes that it is incomplete, especially for the Adirondack Park region of New York. Sizes of reserves are based on estimates from the most rigorous surveys, although some values are still only approximate. For seven stands of old growth in the region acreage is not known and are therefore excluded from the analysis.

Table 11. Water quality with respect to the water's ability to support "designated uses."¹²⁷

| Water-body Type | Waters Assessed | Fully Supporting | Threatened | Partially Supporting | Not Supporting |
|-----------------|-----------------------|------------------|------------|----------------------|----------------|
| Maine | | | | | |
| Rivers | 31,672 mi | 99% | — | <1% | <1% |
| Lakes | 958,776 ac | 70% | 6% | 24% | 0% |
| Estuaries | 1,633 mi ² | 90% | 0% | 2% | 8% |
| New Hampshire | | | | | |
| Rivers | 10,841 mi | 98% | 0% | 1% | 1% |
| Lakes | 153,580 ac | 85% | 6% | 6% | 3% |
| Estuaries | 28 mi ² | 34% | — | — | 66% |
| Oceans | 18 mi | 100% | — | — | — |
| Vermont | | | | | |
| Rivers | 5,264 mi | 59% | 22% | 15% | 4% |
| Lakes/ Ponds | 52,851 ac | 37% | 33% | 20% | 10% |
| Lake Champlain | 174,175 ac | — | — | 46% | 54% |

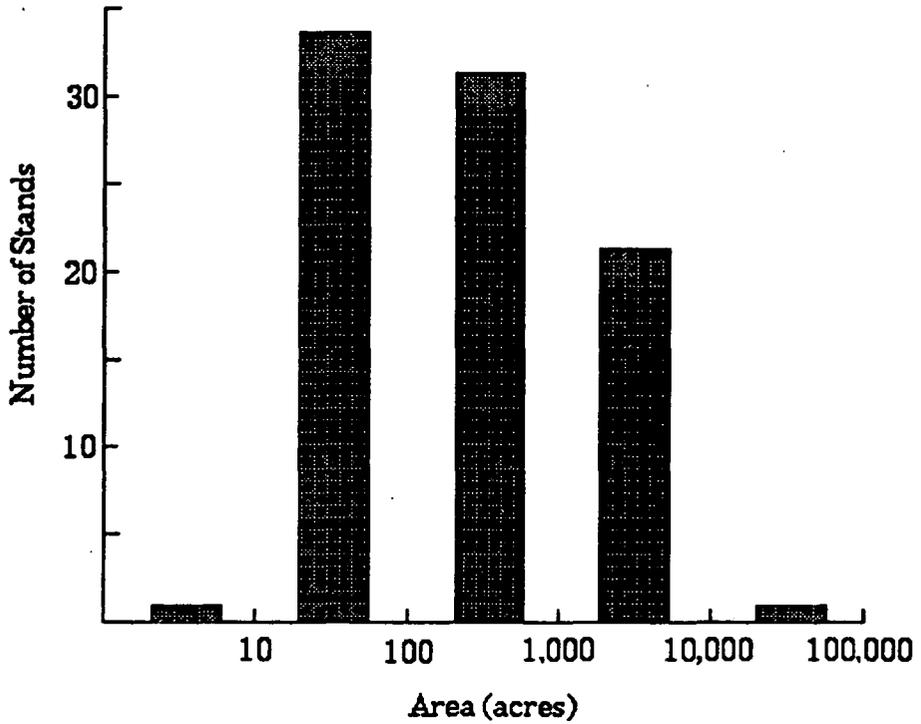
127. ENVIRONMENTAL PROTECTION AGENCY, NATIONAL WATER QUALITY INVENTORY: 1992 REPORT TO CONGRESS (EPA 841-R-94-001) (1994); see also MAINE DEP, *supra* note 110.

Figure 1. Changes over time in the percent of total land area that is forested in northern New England.¹²⁸



128. Litvaitis, *supra* note 39.

Figure 2. Frequency distribution of sizes of old growth stands in the Northern Forest. Note that the horizontal axis is plotted as a logarithmic scale.¹²⁹



129. DAVIS, *supra* note 88.

