Adapting Forest Science, Practice, and Policy to Shifting Ground: From Steady-State Assumptions to Dynamic Change

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Abstract: *What forestry needs in the Anthropogenic Era is what has been needed for the past 30 years. The proper methods, theory, and goals have been clear and are available; the failure has been, and continues to be, that our laws, policies, and actions are misdirected because we confuse a truly scientific base with nonscientific beliefs. The result is a confusion of folklore and science that is counterproductive, both for forests and for human needs and desires. Our love of forests gets confused with our attempts to understand them. In the practical world of incomplete knowledge, our management of forests needs to make use of what I call naturecraftsmanship, the art of science and practice, a sort of General Practitioner's approach to the use of medical research. We will not love forests less but like Thoreau, understanding the distinction, appreciate them more deeply. This paper explains what science, scientific concepts, measurements, and theory could be used, and discusses the deeper dilemma of our confusion of belief and knowledge.*

INTRODUCTION

My work in ecology began in forests, and forests continue to be a major emphasis. I have spent almost half a century trying to understand how forests work, and to use that understanding to solve forest-related environmental problems and to come to know the ways that forests are important to us, in addition to being sources of timber and other resources. I would like to share what I have learned, in the hope that it will improve the way we manage, use, and conserve forests in the 21st century. To understand forests as environments and how we are managing them and should manage and conserve them, we have to deal with three questions: Who owns and controls our forests? How do management and concepts have to change? And what has happened to public attitudes, interests, and appreciation of forests.

FOREST OWNERSHIP HAS CHANGED GREATLY IN THE 21ST CENTURY, WITH MAJOR EFFECTS ON CONSERVATION AND MANAGEMENT

Until the 1980s, most U.S. private forests were owned by 15 major timber corporations, and forest research was expanding. Today, none of the major timber corporations own any significant forestland. They sold their forests, and now the major large private owners are real estate investment trusts (REITs) and timber investment management organizations (TIMOs). From the environmental side, the Nature Conservancy has grown to become one of the largest owners of private forestland in our nation. One cannot overestimate the importance of this change, but oddly, almost nobody knows about it, and almost nobody talks about it.

According to Peter Stein, writing in *Forest History Today,* "By 2004 only six of these fifteen were traditional forest product companies; of the remaining nine, seven were TIMOs and two were REITs. In 2010, only one of the top fifteen U.S. forestland owners was a traditional owner, while ten were TIMOs and four were REITs. In addition, since 1995, more than half of the nation's 68 million acres of private industrial timberland has changed hands, most within the period from 2000 to 2005" (Stein 2011).

Before this change in ownership, forest corporations and environmentalists held many different opinions about how forest should be managed, but both were in it for the long term. Timber companies saw their profit from the sustained yield of their lands. But a primary goal of REITs and TIMOs is to make a profit by buying and selling land. There is less inherent incentive for sustainable forest management. Some REITs seem to be attempting to do a decent job of forest management, but those of us who hope for best management have to add a new level of watchfulness and action.

Forest research and its funding appear to have declined since the 1980s, when forestry was one of the central environmental issues. The traditional timber companies supported their own research, some of it substantial, like that of Weyerhaeuser Corporation. Research conducted by the fifteen previous major traditional timber companies is gone. In addition, a 2002 National Academy of Sciences (NAS) report noted that "the USDA [U.S. Department of Agriculture] Forest Service has experienced a 46 percent decrease in number of scientists in the last 15 years, from 985 in 1985 to 537 in 1999." Since then the number of USFS [U.S. Forest Service] scientists has dropped even more, to 498 in 2008, the most recent estimate I have found (Committee on National Capacity in Forestry Research 2002). I note, however, that because research in forests is funded by DOE, NSF, USGS, NOAA, NASA and EPA in addition to the USFS, and is also funded by some private foundations, the apparent decline stated in the NAS cannot be completely substantiated. Still, the drop in in-house Forest Service research scientists is of concern in itself.

This NAS report warns "the waning Forest Service research base may be challenged as demands on forest resources increase. Enhancing the nation's forestry-research capacity must deal with the tangible matters of substance—funding, facilities and equipment, and personnel—and with intangible matters of perception and values—priorities, organizations, structures, and leadership" (Committee on National Capacity in Forestry Research 2002).

Our current task, therefore, seems much more difficult and complex than it did 30 years ago. Even then, available data were generally inadequate for scientifically guided management. If the NAS report concerning U.S. Forest Service research scientist staff is representative of forest research in general, then it may also be true that today there is less information being collected and available. In addition, the data collected are often based on framings that arenot helpful to today's practitioners.

SOME BASIC PRINCIPLES OF FOREST ECOLOGY

To provide a context to discuss the future of forests, we have to accept that *nothing in the environment is constant; everything is always changing.* Ecosystems, species, and populations continuously vary with or without human influence. There is no balance of nature and there never has been (Botkin 2012; Botkin and others 1991). *Since the environment has always changed, all life has evolved with and adapted to environmental change.* Many species, perhaps most, require environmental change to persist (Heinselman 1973; Covington 2003; Noss and others 2006; Botkin 2012). Another consequence of the ever-changing character of nature is that *there is no single best state of nature*, not in terms of the persistence of species, of ecosystems, nor in terms of what is perceived as most useful and beneficial to people (Botkin 2012).

When people believed in a balance of nature, they also believed that there could be only one best state of nature: a (supposedly) constant state. In an ever-changing nature, it is possible in the abstract that there might be one best state, but in reality this is not the case. Our approach to conservation and management of forests must also include humility: *We can affect, but only partially control, Earth's environment.* As Buckminster Fuller put it, our problem is that we live on a planet that didn't come with an instruction manual. Globally, our environment is a set of very complex systems, none in a steady state, each affecting the others, and which we are only beginning to understand.

Furthermore, *people have altered the environment for at least 10,000 years, probably much longer* (Romer 2013). What people used to consider "virgin" nature—never touched by people—is turning out in surprisingly many cases to have been greatly affected by people. People have altered Earth's land surfaces for thousands of years (Ellis and others 2013). In Switzerland, pollen deposits dating ca 6,700 BCE indicate the presence of agricultural plants, and therefore human land clearing (Tinner and others 2007). And long before the rise of agriculture, people may have altered landscape through fire and played a role in the extinction of species. Miller and others (2005) point out that most of Australia's largest mammals became extinct 50,000 to 45,000 years ago, and speculate that the most likely mechanism would have been human-caused wildfires. So to speak of an Anthropocene Era means we have to speak about many thousands of years, in contrast to today's fashion, whereby in our typical temporally provincial way, we attribute major changes in the biosphere only to ourselves and our forebears since the industrial/scientific revolution. If we are going to speak accurately about an *Anthropocene Era*, then we have to allow that it began at least 10,000 years ago.

I would like to add that our conservation of forests must be approached from an understanding that *there are eight rationales for the conservation of nature: recreational, spiritual, inspirational, cultural, utilitarian, ecological, aesthetic, and moral* (Botkin 2001, 2012). Much modern environmentalism assumes there is only one approach and one solution to any environmental problem, so conflicts among supporters of environmentalism come as a surprise. But different people may assign different priorities to the eight reasons we value the environment, resulting in conflicts even among those who believe they share the same large goals.

HOW CONSERVATION AND MANAGEMENT OF FOREST ECOSYSTEMS MUST CHANGE

Given these principles of forest ecology, a variety of things have to change in our conservation and management of forest ecosystems. First of all, *we have to move away from attempts to keep all forests in a single state.* Because ecosystems have multiple states, and because forest ecosystem conditions often desired by people today are the result of past human alterations, forestry policies that attempt to exclude human actions on all forests must cease because they are necessarily doomed to fail and they sometimes do considerable harm. Although there is greater recognition by such environmental groups as the New Jersey Audubon Society, and often verbal recognition of these changes elsewhere, much policy is still based on "leave forests alone," and public assertions continue to propose the same (Cecil 2013). Smokey the Bear continues to tell us that, "Only you can prevent forest fires."

A study of birds in the Pine Barrens forests of New Jersey illustrates the importance of multiple states of ecosystems. There, the eastern kingbird was 22 times more common in early-successional, heavily managed forests (meaning timbered and managed for sustainable timber harvest) than in old growth. In contrast, the pine warbler was almost twice as common in the unmanaged and older forests than in the heavily managed forests (Williams 2013). If the world were only one or the other, some of the species would die out. In my own research on moose and their food supplies at Isle Royale National Park, it was clear that moose are creatures of young forests. They will not eat the spruce that is dominant in old-age boreal forests on the island, and they eat little of sugar maple, which dominates the old-growth deciduous forests of the island. Moose can reach up to 3 meters, which means that trees in dense and deeply shaded stands, typical of old growth, provide little food for them (Jordan and others 1971; Botkin and others 1973). These are two of many studies for many species that show the same kinds of patterns (Botkin 2012).

Use Better Models and Connect Theory Better with Observations

Ecology has long been theory-rich, but in the past most ecological theory was based on steady-state assumptions, heavily borrowed from simple equations of Newtonian physics. These models tended to be oversimplified and overly generalized, rarely tested against observations, and even when tested and disproved, they continued to be used (Botkin 1993). From the 1980s through the 1990s, it seemed that things improved, but strangely since then movement has been back to either overly simplified or overly complex models. Some recently developed models are intended to account for every variable, including many variables for which observations were not generally available, and so parameters could not be accurately estimated. Therefore, these models could neither be accurately calibrated nor validated. This has been especially true for models used heavily to forecast possible effects of global warming on biodiversity (Botkin and others 2007). These models violate Occam's Razor, in a modern interpretation, meaning that an explanation should be no more complicated than necessary to account for all known observations. A detailed analysis goes beyond the scope of this paper but is reviewed in several of my other publications (Botkin 1993; Botkin 2012; Botkin 2012).

Measure, Measure, Measure

As long as we believed that nature was constant and that a single constant condition was best, we didn't have to know much about it; we could just let forests go, certain that left to themselves they would achieve this single best state. I note that mathematically there are actually three possible assumptions here: first, there is a set of states nature can be in, such that, once any state in that set is achieved, that state is self-perpetuating. This is not, however, the common belief. Another is that there is only one element in that set that can be self-perpetuating. Yet, a third is that regardless of where the forest is today, if humans practice hands-off, then the forest will move towards that happy golden state. The second two possibilities are the ones that are commonly assumed. However, once we accept the ever-changing character of all of nature, including forests, then we have to learn what the possible and characteristic states of a forest are. We must measure key factors and monitor them over time.

In my experience, key variables that are needed to understand how a forest ecosystem works and to solve a forest-related environmental problem have all too often not been measured, and if they were, the data were ignored. Here are some examples. In 1970, when James Janak, James Wallis, and I created the JABOWA computer model of forest growth, the first successful multispecies computer simulation in ecology, the general perception among my ecologist colleagues was that ecology was data-rich and theory-poor. But on the contrary, when we sought data to validate the model, we found that even the most obvious and straightforward data were rarely available (Botkin and others 1970; Botkin and others 1972).

In the 20th century, the U.S. Forest Service claimed that it maintained a series of permanent plots, 30x30 feet (just over 9x9 meters), where the species and diameter of every tree were recorded every ten years (Duncan 2004). I have searched for those data ever since and never found a single plot that was measured more than once using the same methods.

The best long-term monitoring I have found has been done in Australia, and in recent years, I have been working with Australian ecologists Michael Ngugi of the Queensland Herbarium, Toowong, Queensland, Australia and David Dooley, of the University of Queensland, Brisbane, Queensland, Australia, to use these data to further validate a JABOWA-derived model. When people talk about monitoring, typically the implication is that it has to have gone on for a very long time to be useful. But the data we have used from Australia cover 55 years (some as much as 70 years), a comparatively short time for forests. One of the benefits of this data is that methods were consistent, thorough, and extensive throughout the period. The monitoring was done in uneven-aged, mixed-species callitris forests on the 172,000 ha (425,000 acre) St. Mary's State Forest, Queensland, Australia, involving 143,200 trees from 26 species, sampled on 121 plots, each 0.4 ha (1 acre) (Ngugi and Botkin 2012; Ngugi and others 2013).

Although these are among the least known and most degraded forest communities in Australia, they are known habitat for threatened and rare fauna species. The model projections explained 93.9 percent (diameter at breast height (dbh)), 88.9 percent (basal area), 90.5 percent (stem density) and 88.6 percent (aboveground biomass) of the observed variation. To our knowledge, this is one of the most accurate validations of a forest dynamics simulation.

Moreover, as another example of the lack of forest data, in 1991 the state of Oregon passed a bill to fund an objective scientific study of the relative effects of forest practices on salmon, and I was asked to direct it. One would think that a state funding such a study believed that the information necessary to answer the question existed—for example, a map of the state's forest; accurate history of logging by date, location, area cut, and methods; and annual counts of returning adult salmon. However, the state Department of Forestry told us they had no map of the state's current or past forests. A year into the study, the state forester discovered one map, made in 1913, which had been stored in a men's room and saved by a night watchman from being tossed out. We made a current one from Landsat satellite data. Counties, which did not record any information about area cut or methods, gave out logging permits, and these records were destroyed after five years. Of the 23 rivers we were required to study, salmon were counted on only two (Botkin and others 1995).

Even When Data Exist, They Are Sometimes Ignored

Since the 1970s there has been considerable interest in forest biomass and carbon storage. By the 1980s, I knew that the estimates in use had no statistically validity—they were not part of a single uniformed sampling program nor intended to be statistically representative of an entire biome or any large area. They were based on individual studies of forest stands of some particular interest to a scientist, and tended to be old-growth stands, which were considered the most natural and therefore the most interesting ecologically (Woods and others 1991).

I obtained funding to do the first statistically valid estimates of biomass and carbon storage from any large forested areas of Earth: the eastern deciduous forests and the boreal forests of North America (Botkin and Simpson 1990; Botkin, Simpson and others 1992; Botkin, Simpson and others 1993). Results were published in the early 1990s, but to my knowledge have never been used, even in current papers about biomass and carbon storage, and the methods have never been repeated. These statistically valid estimates give a lower range than those found in recent papers. For example, Houghton (2005) summarizes other studies and gives a range of 40.8 to 62.7 Mg/Ha (megagrams carbon per hectare) for boreal and temperate forests of Canada and the United States, while our study gives a mean of 36 ± 6 Mg/Ha for temperate deciduous forests of North America and 19 ± 4 Mg/Ha for North American boreal forests. Thus, our statistically valid estimate includes a value that is 47 percent of that Houghton reports for Canada, which I take to mean boreal forests, and 57 percent of that Houghton reports for the United States, which I take to mean the temperate deciduous forests (Houghton 2005).

My Australian colleagues report two other statistically valid studies, also ignored in the major summaries of carbon storage (Grierson and others 1992) and (Moroni and others 2010). Given the strong emphasis on international forest carbon-sequestering agreements and the funds that will be required, this kind of ignoring or ignorance of available data cannot continue. There is a basic irony here. The need to measure and to do scientific research becomes ever more obvious as the very forest research necessary declines. Adding to this irony is that we live in the information age, often drowning in data.

Declining Interest in Forest Issues

How could these two things happen—lack of monitoring and lack of interest in available data? Part of the answer is the decline in media attention and public interest in forests. Through the

1980s, forests were among the most talked about environmental problems. Most aspects of forest use were the subject of lively discussions, including the importance of old growth, the effects of forests on salmon habitat, the certification of forest practices as sustainable, whether timber corporations and the U.S. Forest Service were managing forests properly, the roles of stages in forest succession other than old growth (Sedjo and Botkin 1997). Certification of forest sustainability continues, but is little discussed broadly, especially regarding whether the methods in use are valid. I note that, in contrast, the certification of forest practices as sustainable remains a lively topic in management and economics.

Today we hear about forests as possible carbon sinks and as players in climate change, and we become alarmed about forests when there are major wildfires. Much of public and media attention about forests is reduced to very simple statements, such as "Stop tropical rain forest deforestation." One of our tasks is to renew public interest in and concern about forests, which in turn may help promote more government and private monitoring and research.

NEW CONCEPTS OF ECOLOGICAL STABILITY

We must change how we characterize what is "normal," "natural," and "desirable" about forests, and about all ecosystems. Prof. Matthew Sobel, William E. Umstattd Professor of Industrial Economics at Case Western Reserve, and I addressed the problem of how to replace the concept of stability in ecology—the assumption that forests were steady-state systems—with analogous concepts that could be applied to dynamic systems (Botkin and Sobel 1975). In most environmental literature, the concept of stability is implicit and vague. Where defined explicitly, the concept was borrowed from, or equivalent to, the classical mechanics definition of a system that will tend to return to an equilibrium state, at rest, after being disturbed. We labeled this property "*static stability*."

We proposed two replacements: *Persistence* within specified bounds, and *recurrence* of previous occupied states. (These definitions were not new in concept, but were used in the mathematics of stochastic processes.) To understand persistence, look at Figure 1, which shows forecasts of the growth of jack pine stands in southern Michigan in a specific, highly sandy soil, the only places where Kirtland's warblers would nest (Botkin and others 1991).

A program to save the habitat of Kirtland's warbler was set up in the state of Michigan with help from the Audubon Society and the U.S. Fish and Wildlife Service. The state set aside 12,140 ha (30,000 acres), in which stands were burned every 30 years. The question we asked was whether the jack pine could regrow in a forecasted global warming climate. The model was run in two scenarios: (1) under 20th century and, (2) forecasted global warming climates. The graph in Figure 1 shows the results for the control scenario, in which the 1950–1980 climate was treated as "normal." Under this climate, the jack pine continues to regrow following fire, just as it had in the past. Each of the previous stages is therefore recurrent. In contrast, under the forecast global-warming climate, by 2010 a jack pine stand of 8 cm^2/m^2 was no longer recurrent, and by today—2013—only the first three basal area levels were forecast to be recurrent. By 2040, the forecast is that jack pine would be completely nonrecurrent. We can therefore say that under global warming the jack pine forests are not recurrent, and therefore this is not what people hoped for with the intentional burning on forest stand, and would cause the local extinction of Kirtland's warbler.

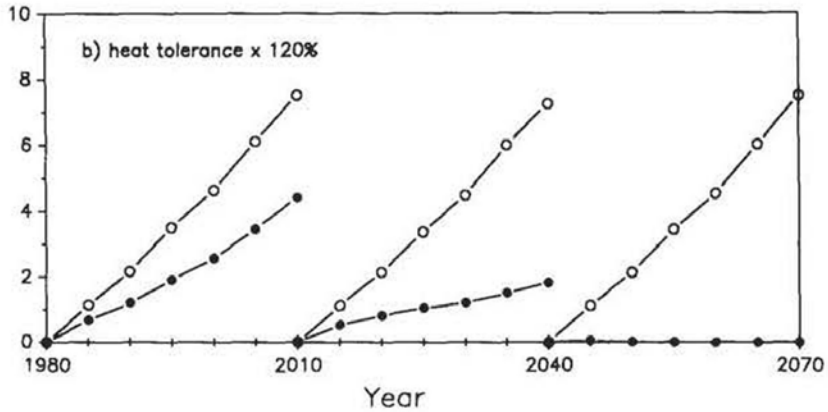

Figure 1. Persistence for simulated growth of two otherwise identical stands.

Persistence Within Bounds

We also need to characterize how the variation in the states of a forest (the trajectory) compares between two different treatments. We call this *persistence*. To make this comparison for dynamic forest systems, we examine a trajectory—a time-series–of each treatment. Figure 2 illustrates persistence for simulated growth of two otherwise identical stands, each harvested every 50 years, one by clear-cutting, the other by a selective cut, which in this case is cutting all trees larger than 12.7cm diameter. The question being asked is: Over a long time, which treatment yields greater quantities of merchantable timber? Figure 2 shows the trajectories of each forest stand. It is clear that after an initial early succession rise, the selectively cut forest maintains a higher yield of merchantable timber than the clear-cut forest. There is no overlap between them. We say that the persistence of the clear-cut forest is completely different from that of the selectively cut forest.

Naturecraftsmanship

The discussion so far raises the question: What do we do when adequate data and formal theory are lacking. In the past, the usual answer was to rely on gut feeling, heavily emotionally and ideologically influenced beliefs, disconnected from long-term observations of any kind, qualitative or

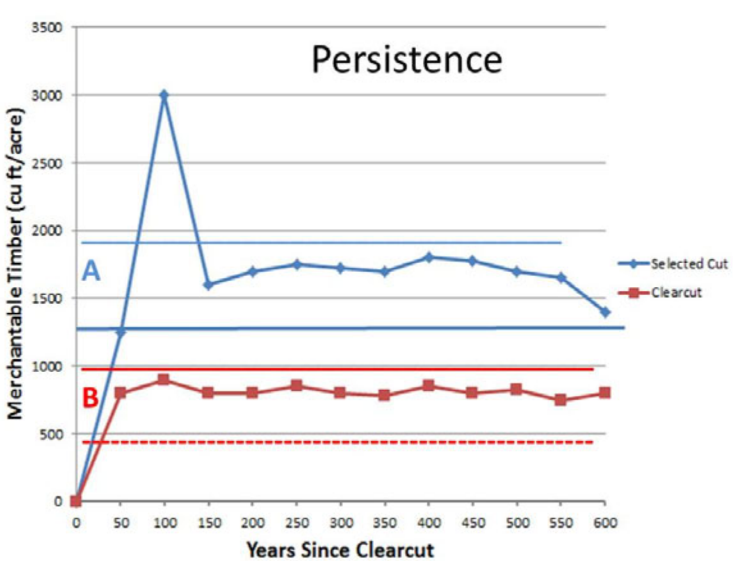

Figure 2. Forecasts of the growth of jack pine stands in southern Michigan.

quantitative. The correct, practical answer is what is known as "woodsmanship." Speaking more generally, we can refer to this as "naturecraftsmanship." I illustrate this with the work of Bob Williams, a certified forester practicing in the Pine Barrens of New Jersey, who received 2013 New Jersey Audubon's Conservationist of the Year Award. In addition to improving the conservation of biodiversity in the unusual oak-pine forests of the southern New Jersey coastal plain, he has successfully planned timber harvests for commercial and government forests for more than twenty years, converting what had become little remembered and poorly cared-for forests into stands that provide valuable timber products and make profits for the landowners.

I spent a day with Bob visiting the forests, seeing stands of many stages and treatments, from ones that had never been logged for a century or more to ones that had been logged last year. At one stop he said he had thinned the forest we looked at. I asked him how he determined how much to remove. I was thinking as a scientist, in terms of carefully measuring the diameter and height of trees, or using other, faster methods to estimate biomass in a locale, or marking individual trees to be thinned out. Bob said he couldn't afford to do these assessments, desirable though they were. Instead, he brought the logger who would cut the trees to an already thinned forest and told him, "I want that other forest to look like this." Then he would train that logger, having him thin trees in a small area and telling him what he needed to change. After enough trials, he would let the logger continue on his own.

Bob listens to and makes use of scientific information. Two science professors were with us on the tour: Chris Williams, wildlife biologist, University of Delaware; and George Zimmermann, Chairman, Environmental Studies, Stockton College. Chris's grad student had just completed the thesis I mentioned earlier, measuring bird use of forest areas of different ages, research that Bob integrated into his thinking.

In the practical world of incomplete knowledge, our management of forests needs to make use of naturecraftsmanship, the art of science and practice, a sort of General Practitioner's approach to the use of medical research. I've worked with and met others who were experts on condors, salmon, and forests elsewhere in our country, who worked that same way. It's what is missing today from the intense environmental debates that capture so much public attention, and which pit ideologies against quantitative science, sometimes leading to the misuse of scientific information, or at least dealing with it in an abstracted way. I contend that "woodsmanship" in its largest sense, perhaps "naturecraftsmanship," is one of the key things lacking in environmentalism today, necessary for us to find ways to help conserve nature and save ourselves. naturecraftsmanship is somewhere between the two dominant approaches to environment these days: scientific research and ideological environmentalism.

To many, the ability to both harvest trees and improve the conservation of nature may seem an oxymoron, but Henry David Thoreau didn't think so, as I explain in one of my ebooks, *No Man's Garden: Thoreau and a New Vision for Civilization and Nature* (Botkin 2001, 2012). Logging per se did not interfere with Thoreau's appreciation of the spiritual qualities of forested nature, as long as the cutting was not so large in area or so severe as to disallow any sense of contact with the forest, or seriously interfered with other land uses, especially when it was destructive to the point that the cutover land could not be used to build cities.

On his first trip to the Maine woods, he met two loggers and wrote, "I often wished since that I was with them," calling their life "solitary and adventurous." He continued this thought in *Walden*, writing, “Fishermen, hunters, woodchoppers, and others, spending their lives in the fields and woods, in a peculiar sense a part of Nature themselves, are often in a more favorable mood for observing her than philosophers or poets, who approach her with expectation” (Thoreau [author], Moldenhauer [ed.]. 1973).

WILDERNESS IN THE TWENTY-FIRST CENTURY

Since there is no longer any part of Earth that is untouched by our actions in some way, either directly or indirectly, there are no wildernesses in the sense of places completely unaffected by people. But there are three kinds of natural areas that we could maintain in the future: no-action wilderness, preagricultural wilderness, and conservation areas.

The first is an area untouched by direct human actions, no matter what happens. This kind of wilderness is necessary for observation as a baseline from which scientists can measure the effects of human actions elsewhere; it is an essential calibration of the dials we should set up to monitor the state of nature. Some may be important for biological diversity. Some may be pleasant for recreation, and some may become a nature never seen before.

The second kind, preagricultural wilderness is an area that has the appearance of landscape or seascape that most closely matches the ideal of wilderness as it has been thought about in recent decades. In North and South America, Australia, New Zealand, and other places in which the time of arrival of modern technological man is readily dated, the idea is to create natural areas that appear as they did when first viewed by European explorers. The first two we can regard as true wilderness and designate legally as protected wilderness areas (Botkin 2012).

Conservation areas, the third type of natural region, are set aside to conserve biological diversity, either for a specific species or for a kind of ecological community. Most require active intervention, as with the habitat of Kirtland’s warbler discussed earlier.

To these kinds of formally designated wilderness, we could add the kind of landscape that Thoreau sought, a place where he could experience *wildness,* a spiritual state existing between a person and nature, which he distinguished from *wilderness,* which was land or water unused at present by people and thus a state of nature. As I discuss in *No Man’s Garden: Thoreau and A New Vision for Civilization and Nature*, wildness meant so much to Thoreau that one day he wrote: “I caught a glimpse of a woodchuck stealing across my path, and felt a strange thrill of savage delight, and was strongly tempted to seize and devour him raw; not that I was hungry then, except for that wildness he represented” (Botkin 2012; Thoreau 1973). For Thoreau it was possible to find this wildness in places quite close to home and civilization, such as Walden. It is much like the idea behind Japanese gardens, meant for reflection and meditation.

SUMMARY

To speak of an Anthropogenic Era, we have to mean an era beginning thousands of years ago, possibly 10,000 or more years ago, when people began to have major effects on the environment, at least in terms of lighting fires, clearing land, and altering the abundance of various animals, some driven to extinction. To deal with forests in our future, we must understand that most of the tools exist and have existed since the 1980s. It is merely a matter of applying them. The major obstacle to this is the dominance of prescientific beliefs about nature, which continue to form the basis of many forestry laws, policies, actions, and attempts to conserve biological diversity. To get past these folktales, we have to change how we characterize what “stability” can mean for non-steady-state-system; how we characterize “normal,” “natural” and “desirable” in regard to forests, as well as about all ecosystems. We have to understand the functions of theory and models for non-steady-state systems. These models require appropriately detailed monitoring of key variables (not every variable). Where monitoring and theory are lacking, naturecraftsmanship–the art and practice of forestry by those familiar with both forests themselves and the best scientific research–is a practical alternative, and should replace the ideological, contrary to scientific, beliefs that still dominate.

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This paper received peer technical review. The content of the paper reflects the views of the authors, who are responsible for the facts and accuracy of the information herein.