CONCEPTUAL FOUNDATION AND PHILOSOPHICAL FRAMEWORK FOR THE ILLINOIS NATURAL AREAS INVENTORY

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Introduction

The purpose of updating the Illinois Natural Areas Inventory is to support efforts to identify, protect, manage, and restore natural lands and waters throughout the state, including areas of statewide as well as local significance. In support of these efforts, the conceptual foundation for the Illinois Natural Areas Inventory Update lies in two fields of study: historical ecology and conservation biology. *Historical ecology* is the study of past ecological conditions. *Conservation biology* addresses the maintenance, loss, and restoration of biological diversity.

Historical Ecology

Natural areas are relics of past conditions. Research into historical ecology provides basic information about the former character of the natural landscape, environment, vegetation, and animal life. [1] *

I began to delve into a conceptual basis for expanding natural area programs in Illinois in 1991. At that time, Brian Anderson of the Illinois Nature Preserves Commission suggested that I see what could be learned from the early literature. I subsequently devoted four years to gathering and studying early eyewitness descriptions of the state's ecological features. During this initial effort, I identified four major, frequently recurring themes in the historical accounts:

Variety
Abundance
People
Change

Again and again while reading early accounts of Illinois, I was struck by the bewildering *variety* in the natural world, and by its immeasurable *abundance*. I also came to realize that *people* have been part of the natural scene for as far back in time as it matters. If there is anything constant in nature, it's *change*. People have often been the agent of this change, controlling the variety and abundance in nature. [2]

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* Superscript numbers denote endnotes, which begin on page 20.

Variety

Variety is synonymous with *diversity*. I choose the word *variety* because *diversity* shares its root with *division*, and I would rather think in terms of *unity*. [3]

Ecological restorationists ponder questions such as, "What was the historic Midwestern savanna like? Did it have big oaks with broad, spreading crowns? Or did it have scrubby little oaks? Was it bedecked with a clean carpet of grass and bejeweled with wildflowers? Or was it an impenetrable tangle of brush?" The answer is yes: the savanna was all this and more.

And how did the forest look where it bordered on the open prairie? One early 19th-century traveler observed as he left the forest, "The trees as we advanced appeared of less and less magnitude, till our path led through oaks of small stature into the prairie." Elsewhere on the forest–prairie border, another early eyewitness reported a quite different view: "The wood does not gradually decrease in size, but remains as lofty as elsewhere, sometimes even to resemble a wall." The natural landscape must have held most every possible combination and permutation of vegetation structure and composition. Nature exhibited abundant variety.

Abundance

Nature in early Illinois was prodigiously productive. Jacques Marquette was the first Frenchman to testify to this fact, in 1673. After traveling all the way from the Great Lakes to the Arkansas River and back by way of Illinois, here is what Father Marquette had to say about the Illinois River:

> We have seen nothing like this river that we enter, as regards its fertility of soil, its prairies and woods; its buffaloes, elk, deer, raccoons, geese, swans, ducks, parakeets, and even beaver. [4]

Fourteen years later, in the winter of 1687–88, Henri Joutel was marooned in Illinois — midway on a horrific trek from the Texas Gulf Coast to Montreal. Despite his trying situation, Joutel wrote this about Illinois:

> As to the aspect of the country, it could not be more beautiful, and I may say that the land of the Illinois is perfect; everything necessary to life and subsistence can be obtained, for, in addition to the beauty with which it is adorned, it possesses fertility. [5]

Missionary Father Sebastien Rasles reported to his superiors in 1723,

> Of all the nations of Canada, there are none who live in so great abundance of everything as the Illinois. Their rivers are covered with swans, geese, ducks, and teals. One can scarcely travel a league without finding a prodigious multitude of turkeys, who keep together in flocks, often to the number of two hundred. [6]

In 1752 a French soldier encountered "a type of wild wood pigeon" (*i.e.* the passenger pigeon) "in such thick clouds that they eclipse the sun" near the mouth of the Ohio River. While stranded at the southern tip of Illinois during the winter of 1810–11, John James Audubon witnessed "thousands of paroquettes" (Carolina parakeets) roosting in hollow sycamores at the mouth of the Cache River.

Some early accounts tax the imagination. A mill on the Fox River at Elgin had to shut down repeatedly because migrating swarms of eels clogged the waterwheel. The lower reaches of the Illinois River were so choked with beds of aquatic plants that only a narrow channel in midstream provided a clear passage for boats.

People

People came to Illinois thousands of years ago, not long after the last glaciers retreated from the region. The state's mosaic of grassland and deciduous forest subsequently developed under the continual influence of people. From the beginning of their long tenure in the state, people have exerted big ecological impacts. Early people appear to have had the most influence on the state's ecology in two ways: by killing animals, and by setting fire to the vegetation.

Hunting by people has been implicated in the extinction of dozens of species of large mammals in North America at the end of the Pleistocene. [7] Just think: What if mammoths had escaped extinction and managed to adapt to the Midwestern prairie — and then survived into the 1700s?

Archaeological research shows that the introduction of the bow and arrow about 600 A.D. caused a dramatic increase in the number of deer that were killed by hunters. Within a few human generations, the deer population appears to have declined significantly, presumably because bow-hunting was so effective. Hunting pressures may have also prevented bison from developing and sustaining a large population east of the Mississippi River until around the year 1600. [8] By that time, European diseases had decimated the native human population; researchers believe that bison were then able to expand eastward across this largely depopulated region all the way to the Atlantic coast.

Over the past millennia, people have burned off the landscape so often that the distribution, structure, and composition of the state's native vegetation were largely controlled by fire. Prairies and other fire-dependent plant communities developed on upland plains and other landscapes that carry fires easily. Dense forests and other fire-sensitive communities were restricted to areas that burned infrequently or not at all, such as lowlands bordered by streams and other natural firebreaks. But large prairies occurred even in low, moist, protected situations around riverside settlements, where centuries of human-set fires maintained open grassland in an environment that would have otherwise been naturally forested. [9]

Change

Living things are in constant flux: reproducing, growing, moving, competing, dying . . . . Change is so much a part of nature that "nature preservation" can be considered an oxymoron — if *to preserve* is defined as "to maintain something in its original or existing state." Some of the changes in nature are caused by people; others occur regardless of human activities. Often these two kinds of change are interrelated: actions by people can start a cascade of effects that spread and ramify throughout an ecosystem without any further human involvement.

People have drastically and permanently modified ecosystems and ecological processes in Illinois. The extinction of one species may have profound effects on others. For instance Carolina parakeets appear to have been the only significant aerial dispersers of bald cypress seeds, and now these birds are all gone. [10]

Passenger pigeons no longer provide prey for "pigeon hawks" (which are now known as peregrine falcons, Cooper's hawks, and merlins). Passenger pigeons no longer scarify and disseminate the seeds of an assortment of plants that were once known variously as pigeon grass, pigeon berry, or pigeon pea. Since the passenger pigeon's demise, there must have been a decline in the abundance of pigeon peas and other legumes — with far-reaching effects on nitrogen cycling as well as the population levels of myriad insects, rodents, and birds that feed on leguminous seeds.

The human impacts on individual species pale in comparison to the wholesale erasure and alteration of natural habitats. Historical literature preserves a record of how the ecology of the state changed in response to the influx of European immigrants during the 1800s. [11] For instance prairie-chicken populations boomed temporarily as farms were carved out of the prairie. For a period of a few decades until the prairie was mostly plowed up and grazed down, prairie-chickens enjoyed "the best of both worlds": they had access to farm crops for food, but there was also plenty of grassland to provide protective cover and nesting sites. Prairie-chickens also benefitted when farmers persecuted predatory coyotes.

The "Presettlement Paradigm"

"Presettlement conditions" and "presettlement vegetation" are commonly used as a target or benchmark for identifying, managing, and restoring natural areas. According to this viewpoint, the goal is to protect remnants of presettlement vegetation and to restore lands and waters to the condition that they were in when the area was first settled. The flora and fauna of a site can never be the same as it was in the distant past, so preservationists and restorationists often replace the term *presettlement conditions* with a phrase such as "reflecting the original natural conditions." Although the "presettlement paradigm" has been employed for decades, its suitability for the Illinois Natural Areas Inventory needs to be examined.

The "presettlement" era in Illinois has been defined as the time before the state was densely occupied by people of European descent in the 1800s. This date is a moving target because the state was not populated in this manner all at once. The floodtide of immigration generally began at the southern tip of the state and gradually spread northward — but there were many exceptions. There were outlying population centers, and there were poorly populated enclaves surrounded by more densely settled regions.

A widely accepted date for the end of the presettlement era is the time of the Public Land Survey (PLS), which was conducted by the U.S. General Land Office, predecessor of the Bureau of Land Management. This project platted the entire state into townships and square-mile sections in order to prepare the land for sale into private ownership. Surveying began in southern Illinois in 1804 and advanced northward. The project was all but completed by 1856.

A big advantage of choosing the PLS to define the point in time between "presettlement" and "settlement" (or "post-settlement") is that the PLS surveyors kept records of the vegetation and the condition of the land along every mile that they surveyed. These notes are indispensable and unmatched storehouses of information about the past. The PLS prepared maps to show the extent of timbered areas, prairies, and bodies of water in each township in the state. Many biologists and geographers have used these records to construct "presettlement vegetation" maps and descriptions of the former landscape.

The U.S. Public Land Survey's notes and maps of land cover are the single most systematic and comprehensive source of information about the ecology of early Illinois — but the Public Land Survey provides a snapshot of a moving target, not a portrait of a fixed benchmark. The presettlement paradigm operates under four big drawbacks. Briefly stated:

- *People did it*. The ecology of "presettlement" Illinois developed under a strong human influence.

- *It was a moving target*. The ecology of the state was rapidly and radically changing during the close of the "presettlement" era.

- *It would have kept changing anyway*. The ecology of Illinois would have continued to evolve during the past two centuries even if the land had not been "settled."

- *We can't put it back the way it was*. The state's ecology has been altered so drastically that it cannot be restored to former conditions.

Each of these points is stated more fully and formally below. All four statements could be the subject of an extended essay, but further discussion is limited to an endnote for each one:

- Illinois has been peopled for thousands of years. From the very beginning, the state's current natural communities have developed under the long-term influence of people. Human impact on the state's ecology reaches as far back in history as is relevant to the origin and development of today's natural communities. [12]

- The ecology of the state was in the process of undergoing substantial and unprecedented changes during the decades leading up to the so-called presettlement benchmark era, when the U.S. Public Land Survey was conducted. [13]

- Even if Europeans had never come to America, the state's natural communities would have continued to evolve during the two centuries since the start of the Public Land Survey. [14]

- Today's environmental conditions are radically different from the past, so it is impossible to find "presettlement" conditions, or to restore a site to those characteristics. [15]

A more specific concern is that "presettlement" is the wrong reference point for many sites listed by the Illinois Natural Areas Inventory. Today's old-growth forested stand is not likely to have originated in "presettlement" times. Instead it may be what sprang up from brushy oak and hickory "grubs" after farmers put a stop to prairie fires. [16] Or the forest may have once been a stand of trees that were not quite big enough to cut when the area was last logged. Or it may be the product of wholesale clearcutting followed by a century and a half of recovery. Often it is more important to understand the last century of disturbances in a natural area than it is to know about the area's character two centuries ago.

A broader concern is that the term "presettlement" disavows 500 generations of people who lived out their lives in Illinois. One might argue that "Indians weren't really settled." Indians once had to move from place to place to procure food as it came into season at different locations throughout the year; they did not have the modern advantage of a food-delivery network with a global reach. However, the average 18th-century Kickapoo must have covered less ground in a year than many of us routinely travel in a day.

Even though the presettlement paradigm has big limitations, the so-called "settlers" of the 1800s unarguably had the biggest ecological impact on the state since the retreat of the glaciers. But "settlement" and "presettlement" are not the right terms to denote the beginning of this era of transformation. In 1950 Alfred Meyer, a geographer who carried out pioneering studies of the region around the south end of Lake Michigan, introduced the term *fundament* as a substitute for "presettlement" in a paper titled "Fundament Vegetation of the Calumet Region." Although Professor Meyer's term has not gained wide acceptance, I have not identified a better alternative.

New Insights from Old Sources

Early descriptions of the ecology of Illinois from travelers, residents, and historians provide a substantial body of knowledge about a wide variety of subjects — such as: (a) the impact of severe winters on wild animals and plants, (b) the effects of habitat fragmentation on animal life, (c) the role of predation in regulating animal numbers (and the resulting responses of vegetation to those changes in wildlife populations), (d) the consequences of controlling wildfires, (e) the direct and indirect effects of farming on wetlands and groundwater levels, and (f) the past character of headwater stream channels.

The Natural Areas Inventory must contend with nature's bewildering variety. Historical ecology research can assist by uncovering unusual natural features that might otherwise remain long-forgotten and overlooked: for example "lost rocks," "prairie circles," "hazel roughs," "boneyards," "tar springs," and "licks."

The Inventory faces tough questions about the ever-changing character of the natural world. How do we deal with the fact that the landscape in general is drier — and the climate near the ground is less humid — since water is now constantly bled away wholesale by ditches, gullies, and drainage tiles? How do we treat natural shrublands, which tend to grow up quickly into something else? How do we address the fact that oak–hickory woodlands are turning into maple forests? What about plant species that cannot produce or spread their seeds without the aid of certain animals that are no longer present? By revealing "how things used to be," historical research can help answer these questions.

Historical investigations not only demonstrate that "things aren't like they used to be" — but also that "things weren't like we think they were." Below is a sampling of common misconceptions and other mistaken ideas about the ecology of early Illinois.

Over-generalizations and misconceptions about Illinois' past:	**What the historical record shows about past conditions:**
Forests were generally undisturbed and were dominated by big, old trees.	Most forests were frequented by fires, and the overstory trees were often relatively youthful.
Prairie grass was "taller than a man on horseback."	Vast areas were cloaked with grass that was shorter than knee-high.
Hill prairies are natural openings in the forest.	Hill prairies were formerly the most open part of an open woodland. The woods has since grown denser, leaving the prairies as distinct, isolated openings surrounded by forest.
Lightning was a significant cause of prairie fires.	There are almost no eyewitness accounts of lightning setting a prairie on fire.
The land was well watered, and streamflow was reliable.	Travelers on the upland plains often suffered from lack of water during the summer months. Creeks dried up.
Headwater drainageways were broad, shallow, vegetated swales, with no distinct channel.	Some drainageways were as described in the left column, but some had distinct, open channels with eroded banks.
Big floods are the product of farming and urbanization of watersheds.	Two of the greatest floods on the Mississippi River were in 1785 and 1844 — before the watershed was converted to farms and towns.
Herds of hundreds of thousands of bison covered the prairies.	400 bison was a sizeable herd in Illinois.
Fish kills are the result of modern assaults on the aquatic environment.	There were significant summertime fish kills in Illinois River backwaters.
Canada lynx were never native to Illinois during historic times.	Several accounts of wild cats in 19th-century Illinois match the description of the lynx.
Muskellunge were limited to Lake Michigan and did not occur in inland waters.	Muskellunge occurred in the Fox River basin as well as Lake Michigan.
The Midwest experienced its most severe drought during the 1930s.	The drought of 1819–20 appears to have been about as severe.

Past, Present, and Future

Natural areas can be viewed in three time frames: the past, present, and future. The *past* is key because natural areas are relics of the past. The *present* is the context in which we deal with natural areas. The *future* is important because we want to ensure that natural areas will be maintained in perpetuity. This *past–present–future* view of natural areas is embodied in the term *natural heritage*: that is, something that is inherited from the past and will be continued into the future. [17]

I discuss the Illinois Natural Areas Inventory's natural community classification system in a separate paper (White 2007). When protecting and managing a natural area, it is useful to classify each of its natural communities in three ways: What is it now? What was it in the past? What will it be (or what do we want it to be) in the future?

Conservation Biology

The science of conservation biology first developed with a focus on maintaining genetically viable populations of endangered species. Another major aspect of conservation biology is *preserve selection and design*: that is, how does one identify significant natural areas and then draw boundaries around them that will help ensure that the natural features will remain viable in the long term? This question is addressed in the final section of this paper (pages 11 to 17), and it is the subject of two other documents prepared the Illinois Natural Areas Inventory Update: a *Survey Manual* (White 2008*a*) and *Survey Standards and Guidelines* (White 2008*b*).

Information Resources

Six sets of information about historical ecology are most relevant to the Illinois Natural Areas Inventory:

- Early literature, including first-person accounts by explorers, missionaries, travel writers, local residents, engineers, scientists, and historians.
- Secondary publications such as anthologies and retrospective historical documents that are based on earlier works.
- Field notes and plats of the U.S. Public Land Survey. These are discussed on page 6.
- Old maps in addition to the township plats that were prepared by the U.S. Public Land Survey. These maps date as far back as the first European explorations in the 1600s.

- Early landscape illustrations, including sketches, paintings, and photographs. These resources are especially useful in the context of *repeat photography*, in which an old illustration is paired with a new photo of the same view. [18]

- Early sets of aerial photography, beginning in the late 1930s. [19]

Information that is most useful to conservation biology is available from three primary sources:

- Biological and ecological studies that have been published by the Illinois Natural History Survey, Illinois State Academy of Science, and many specialty groups (herpetologists, ornithologists, etc.).

- Conservation biology periodicals such as *Natural Areas Journal* and *Ecological Restoration*.

- A number of recent books, including college texts.

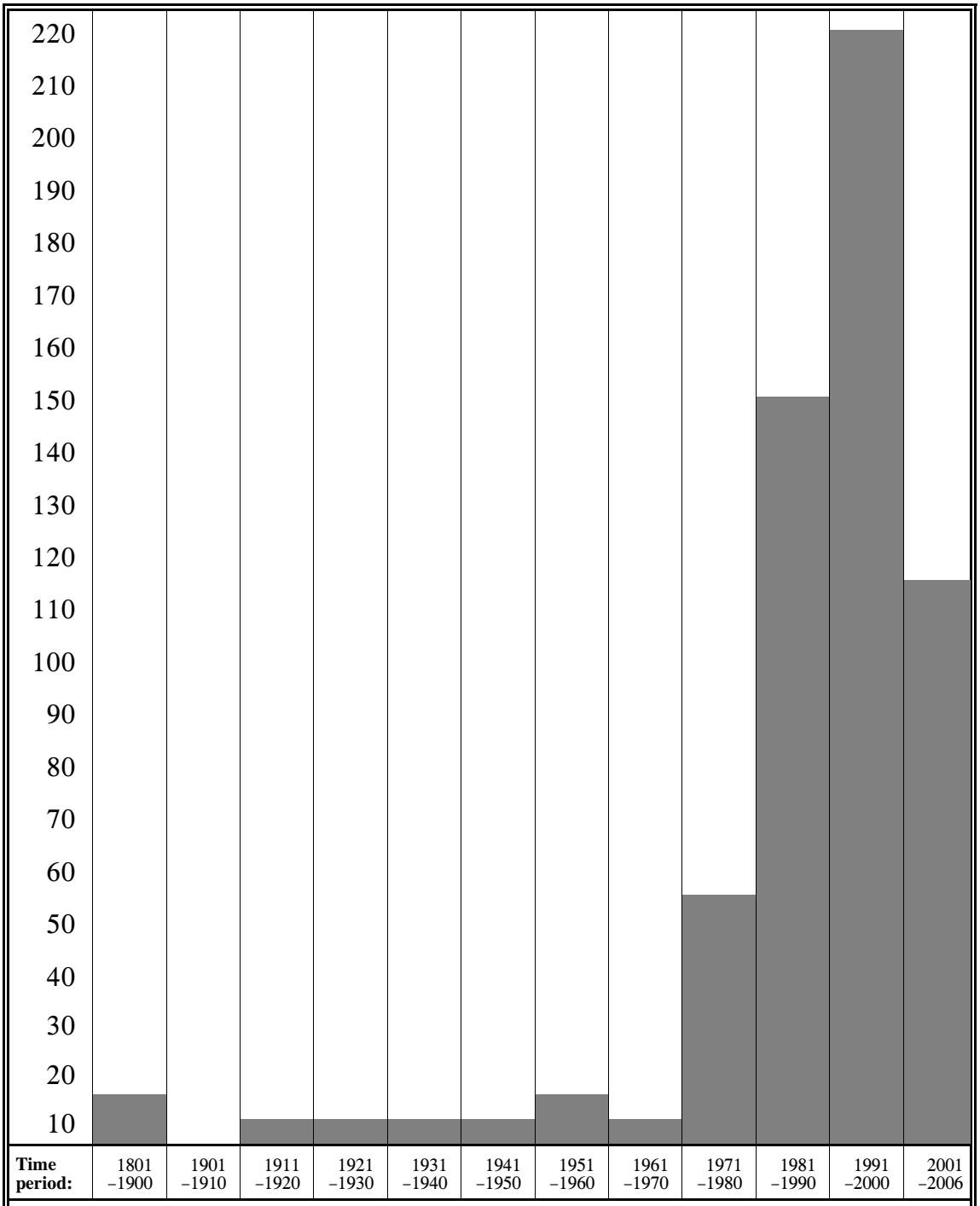
The Illinois Natural Areas Inventory Update will need to assemble and analyze a large body of published works. The act of inventorying these existing information sources is akin to "doing your homework" — by taking advantage of the wealth of knowledge that is preserved in writings, maps, and illustrations.

The literature of conservation biology is burgeoning; see the graph on the next page. In terms of staffing and labor, reviewing both the historical and modern literature will require an effort approximately equal to the Inventory Update's survey to find and evaluate Category I natural areas.

Implications for Natural Area Programs

Natural area programs consist of a set of four distinct but interdependent endeavors: *identification*, *protection*, *stewardship*, and *defense* of natural areas. The Illinois Natural Areas Inventory addresses the first step in this series. The Inventory Update needs to be designed and carried out with the other three steps in mind in order to ensure that the results of the Update are most useful to natural area programs.

In the quarter century since the original Illinois Natural Areas Inventory project was completed, there has been a big increase in the capacity to protect natural areas at both the state and local levels. In 1992 I drafted a mission statement with a set of goals for an expansion of the state's natural area protection efforts. This document, which is in the Appendix, should be reexamined to determine what parts of it can and should yet be incorporated into Illinois' natural area programs.



This graph shows the number of publications that are listed in the bibliography of the fifth edition of the Illinois Natural Areas Inventory Update's *Survey Standards and Guidelines* (White 2006), grouped according to the date of publication. Numbers are rounded to the nearest five publications. NOTE: Each time period spans one decade, except for the first column (which is a century) and the last column (which includes only six years).

On the following pages are a series of brief suggestions and directions for the Natural Areas Inventory Update. This draft discussion is preliminary and incomplete. It needs the benefit of further research, thought, and review and contributions by others.

Think *small*.

Almost "by definition," a natural area in Illinois is likely to be relatively small. There are no big pristine areas. For many kinds of natural communities, the only high quality examples are small fragments. Habitats of many endangered species are often small areas too.

A conservation biologist might counsel that small, isolated preserves are not viable in the long term. Small areas certainly do have big limitations as preserves, but they should not necessarily be written off. For instance, a number of tiny remnant prairies have endured more than a century and a half of abusive neglect in cemeteries that are surrounded by miles and miles of cropland. The mere fact that these cemetery prairies still exist is telling: it tells us that such tiny remnants should not be written off as "not viable." [20]

For a goodly number of good reasons, big natural areas are generally preferable to small ones, but the Natural Areas Inventory must not overlook small sites.

Think *big*.

Many species of animals need large areas of habitat; often these areas do not need to be undisturbed in order to provide the requisite living conditions. The Natural Areas Inventory needs to apply specific criteria and special procedures to identify sites that qualify as natural areas because they provide habitat for animals that require large areas.

Extensive areas also need to be included in an adequate system of natural areas because ecological processes such as animal migration and flood cycles operate on a scale that is far bigger than the biggest of natural areas — extending across both wildlands and disturbed lands.

Think *diversity*.

Preservation of natural diversity is such a fundamental tenet of natural area programs that it is a recurring theme in the Appendix, which spells out a mission and goals for a statewide ecological reserve program. See the discussions in the Appendix under the headings *Natural Diversity*, *Mosaics of Natural Communities and Successional Stages*, *Habitats for Area-Sensitive Animals*, and *Long-term Survival of Native Species*.

Analyze the *viability* of natural areas.

Not all natural areas are equal. Some of them are more likely than others to survive into the future. The Natural Areas Inventory needs to analyze the long-term viability of the sites that it identifies.

Think *restoration*.

In Illinois (and most other parts of the world), if a site is to be managed as a natural area, it is likely to include land that needs to be restored. Ecological processes need to be reintroduced; natural communities need to be rehabilitated or reassembled; native plants and animals need to be reestablished; physical features need to be reconstructed. Restoration is so basic to caring for natural areas that it is not always useful to make a distinction among *protection*, *management*, and *restoration* efforts.

The original Illinois Natural Areas Inventory placed very little emphasis on the potential for restoration when evaluating candidate natural areas. [21] The Inventory Update needs to consider restoration potential when evaluating sites.

Establish *arks* and *archipelagoes*.

In the "ark–archipelago" protection model, a large site plus several nearby, smaller "satellite" areas come under protection and management. The archipelago consists of the small preserves (islands of natural habitat), and the ark is a large restoration site where biota from these local remnants can be established. Plants that are grown and harvested at the restoration site can then be used to re-vegetate other lands in the region — thus increasing the foundation of local genetic diversity of native species.

Application of this model will require that the Illinois Natural Areas Inventory identify both large and small sites.

Use *zones*.

A three-level zoning system is useful for laying out protection strategies. (1) According to this scheme, the central zone, or *preserve*, is strictly protected and managed to maintain its significant natural features. (2) The adjacent *conservation area* consists of wildland which is open to uses that are compatible with maintaining the core preserve area. (3) The *transition zone* includes surrounding agricultural and developed areas where the use of the land has a direct impact on the preserve and conservation area. [22]

Recognize that farmers can be allies and good neighbors.

The diversity of prairie, savanna, and open woodland plants and animals is often substantially higher in a woodlot that is periodically logged and lightly grazed — compared to the diversity of a similar woods that has been set aside as a preserve. Once a wooded area is protected from disturbances, the populations of many endangered plants are bound to decline as the forest canopy closes and shades out the sun-loving herbaceous flora. Lightly grazed or infrequently mowed prairies sometimes have more rare plants than similar prairies that either have long been undisturbed or have been managed with fire.

Although farming can have a host of negative impacts on adjacent wildlands, farmland usually is better than a residential development in terms of providing buffer to a natural area. As they say, "The only thing worse than farmland next to a natural area is anything else."

Don't be too attached to classification systems and definitions of natural communities.

Nature is diverse, and it resists pigeonholing. When conducting an on-site examination of a potential natural area, one should not necessarily write off an example of a natural community as "unnatural" or "nonqualifying" simply because it does not fit the template of the Illinois Natural Areas Inventory's natural community classification system.

A further caution: it may be misguided to try to manage a site with the goal of restoring it to a preconceived prescription of what its natural communities should be. Instead it may be better to carry out activities such as controlling exotic species, reintroducing natural processes to the extent possible, and monitoring changes as "nature takes its course."

Don't assume that the "latest word" and all of the current truisms are true.

The fields of ecology and conservation science have changed over the years as a certain idea temporarily held sway — and then went out of fashion and was replaced by a new school of thought. Dr. Henry Cowles of the University of Chicago, who was the founder of the science of plant ecology in America, saw *physiography*, *climate*, and *time* to be the ultimate determinants of plant communities. On the rare occasions when Cowles wrote about the impact of fire on vegetation, he was apt to discuss it in a negative way. Students of Professor Cowles interpreted the vegetation in the same manner.

Now ecologists who look at the same vegetation that Cowles studied are likely to explain its characteristics in terms of fire history. How certain can we be that

today's ecologists are not underestimating some other important factor because they are so strongly influenced by a fire paradigm? The "next wave" of research may instead emphasize the role of herbivores in shaping vegetation. [23]

Establish research and monitoring points and plots.

One of the biggest benefits of the original Illinois Natural Areas Inventory has been the set of sampling data that now serves as a baseline for measuring changes in the structure and composition of vegetation in natural areas over the past quarter century. [24]

Recognize that much more needs to be done than simply protecting the kinds of sites that were identified by the original Illinois Natural Areas Inventory project.

The Illinois Natural Areas Inventory and Illinois Nature Preserves Commission have placed a special emphasis on protecting and managing high quality remnant natural areas. These sites are often small, and they are irreplaceably precious — yet it is not adequate to protect only them. Large, diverse areas also need to be conserved. Since the original Natural Areas Inventory was completed, the Nature Preserves Commission's program of Land and Water Reserves has been established to help meet this need. Commonplace wildlands must be cared for — not just prairies, small stands of old forest, and other rare natural areas. Going beyond the purview of the Illinois Natural Areas Inventory, the entire natural environment needs to be protected from degradation.

I expressed this viewpoint at the conclusion of the original Natural Areas Inventory, in the final three paragraphs of the *Technical Report*:

> The Inventory selected relatively small, specific sites that merit special efforts for immediate protection, but preserving these sites alone will not ensure that natural diversity is protected. Large tracts of forest, wetland, and grassland need to be maintained. Many animals rely on such large areas for feeding, breeding, and resting. These areas do not necessarily need to be removed from use by people. They can sometimes have uses such as timber production, flood control, and recreation. Not all native plants can maintain their populations indefinitely in small, isolated sanctuaries without the benefit of corridors of natural land so that plant migrations can balance local extinctions.
>
> All aspects of our natural environment need to be protected. Unless soil erosion, air and water pollution, and transformation of wildland into farmland and urban areas are controlled, native animals and plants will

become further endangered, and preserved areas will become little more than museum pieces.

> Preservation of sites identified by the Inventory is an important part of conservation of natural resources. These natural areas are the best remaining examples of our natural heritage, and they are irreplaceable refuges for an abundance and diversity of natural features. They are valuable historical resources, and they are models and sources from which other areas can be restored. Preservation of these areas will be a key to successfully maintaining a healthy and productive environment. [25]

The ongoing Critical Trends Assessment Project of the Illinois Department of Natural Resources is key to efforts to improve and maintain the quality of the environment.

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Endnotes

1. The Illinois Natural Areas Inventory recognizes seven categories of natural areas. This paper focuses primarily on sites that have high quality, relatively undisturbed natural communities; these fall into either Category I (terrestrial and wetland natural communities) or Category VII (aquatic communities). Category IV includes geologic features. The remaining four categories are based on biological features such as endangered species. For a discussion of natural area categories, see the Illinois Natural Areas Inventory Update's *Survey Manual* (White 2008*a*).

2. In 1993 I identified four major themes in early descriptions of the ecology of Illinois: *variety*, *abundance*, *people*, and *change*. In 2004 I attended a lecture by Steven Apfelbaum of Applied Ecological Services, in which he enumerated four major traits of healthy ecosystems. He characterized healthy ecosystems as *diverse*, *dynamic*, *productive*, and *stingy*. The first three of these four traits are equivalent to three of the four themes that I had independently identified in 1993. (The characteristics that Steve enumerated are stated as adjectives, and mine are nouns.) Steve's *diverse* is the same as my *variety*, Steve's *dynamic* is the same as *change*, and *productive* is the same as *abundance*.

   A healthy ecosystem is "stingy" in the sense that nutrients and other materials are closely held by organisms and are slowly cycled through an ecosystem. The stingy nature of a healthy ecosystem is quite evident during scientific investigations, but this trait was not frequently mentioned by early chroniclers of the natural landscape — so I did not identify ecosystem stinginess as a major theme in historical narratives.

   Since his 2004 lecture, Steve Apfelbaum has continued to expand his list of ecosystem traits beyond the four that he first identified; the list now includes a wide range of other ecosystem characteristics, such as *redundant* and *self-organized*. Steve also recognizes the role of *people* (my fourth theme) in ecosystems, but he addresses people in a different context, as a "cultural" element that fits elsewhere in his concept paper.

3. I first saw the word *variety* used in this manner in a book titled *Why Preserve Natural Variety?* by Brian Norton (1987), but the term "variety" has not replaced "diversity" as a catchword among conservationists.

   In the 1970s the American conservation movement embraced the theme of *natural diversity* — as spelled out in the book *Preserving Our Natural Heritage*, which was prepared by The Nature Conservancy in 1977. During the 1980s the focus of conservation efforts narrowed to the living part of the

natural world, or *biological diversity*; the phrase itself soon contracted to *biodiversity*. In recent years there has been increasing interest in *genetic diversity* — that is, *genes* rather than species, ecosystems, or nature as a whole. But at the same time, there has also been more and more recognition of the value of the non-living components of natural diversity — for instance cave minerals as well as cave-dwelling creatures, and fossil deposits in addition to living organisms.

4. Marquette's report reads, *Nous n'avons rien vue de semblable a cette riviere oú nous entrons pour la bonté de terres, des prairies, des bois, des boeufs, des cerfs, des chevreux, des chatz sauvages, des outardes, des cygnes, des canards, des perroquetz, et mesmes des castors* (Thwaites 1900).

   In English-language versions of Marquette's narrative, *chatz sauvages* and *outardes* have traditionally been translated literally as "wild cats" or "wildcats" and "bustards." However, I have interpreted these French words as "raccoons" and "geese." *La chat sauvage* is the old French name for the raccoon, not for the wildcat or bobcat. The early French applied the name *les outardes* ("bustards") to geese, especially species other than the Canada goose. See White (2000:10–11, 37–38) for in-depth discussions of these French names and their English equivalents.

5. This quotation is from Joutel (1714).

6. This quotation is from Kip (1866).

7. I would place my bet (and the blame) on overhunting by people as the cause for the extinction of so many species of large mammals in the Americas at the end of the Pleistocene — but some specialists do not find the evidence compelling. The leading alternative theory to explain these extinctions is a rapidly changing climate and the habitat disruptions that attended this climatic shift. See < www.cpluhna.nau.edu/Biota/ megafauna_extinctions.htm > for a good discussion of these and other theories.

8. In an article titled "Bison in Illinois Archaeology, Griffin and Wray (1945) concluded that "the bison appeared east of the Mississippi in large numbers no earlier than 1600 and became extinct in this area by 1800." However, over the past half century, more and more remains of ancient bison have been uncovered from archaeological and paleontological sites throughout the state. McMillan (2006) compiled and analyzed 133 records of old bison bones from 44 Illinois counties and concluded that bison entered Illinois about 8,000 years ago, began to increase in numbers about 4,000 years ago, and increased dramatically after the year 1500 A.D.

9. The distribution and composition of the state's vegetation was strongly influenced by fires that people set. See two sets of Survey Standards and Guidelines, titled "Fire and Burned Area," and "Natural Disturbances in General" (in White 2008*b*). Compared to human incendiary activities, lightning appears to have had a minor role in setting the Illinois landscape afire. In a decade and a half of research, I have found only one uncertain eyewitness report of lightning starting a prairie fire in Illinois.

10. The reason for the Carolina parakeet's extinction is not known. Noel Snyder (2004) has prepared the most recent and most careful examination of this mystery. Snyder concluded that diseases that were introduced to America with domestic poultry may have been the ultimate factor in the demise of the only parrot native to the United States.

11. The great majority of non-indigenous people who came to live in Illinois during the 1600s, 1700s, and 1800s were from Europe or had European ancestors, but the notion of "European settlement" is not always apt. For instance, some history buffs are fond of saying, "The first white man to settle in Chicago was a black man" (Haiti-born Jean Baptiste Pointe du Sable, who was of mixed African and European parentage).

12. *Illinois has been peopled for thousands of years. From the very beginning, the state's current natural communities have developed under the long-term influence of people. Human impact on the state's ecology reaches as far back in history as is relevant to the origin and development of today's natural communities.*

    There has long been a minor industry among anthropologists and archaeologists writing about human "resource exploitation" and "settlement patterns" in Illinois and the surrounding region — extending far back prior to the French colonial period. Archaeological evidence shows that there have been tens of thousands of settlements in Illinois over a period of thousands of years. In many stream valleys, essentially every elevated site next to every body of water (or former body of water) has some evidence of human occupation. This evidence is so pervasive because stone artifacts are practically immutable, and they have accumulated over millennia. The cumulative story told by these artifacts is that Illinois has been peopled for a very long time.

    Archaeological research shows that many of the habitation sites — maybe most of them — were small and were used only periodically. Although any particular place may have been inhabited intermittently and for short periods, the site may have seen people return annually at a certain season. Many settlements were temporary encampments, part of a series of sites

that people visited regularly at different times of the year — perhaps arriving at one place to spear fish in the spring, another place to raise crops in the summer, and yet another place to gather nuts in the autumn, then south or west to hunt bison in the winter. With this dispersed system for obtaining and growing food, certain locales in the state were intermittently and repeatedly occupied or "settled." When corn became a staple crop after 800 A.D., year-round settlements developed and spread throughout the state. These ranged in size from farmsteads and villages to Cahokia, the largest city in North America.

Native people were already having a tremendous impact on the environment and biota of Illinois before Europeans began colonizing North America in the 1500s and 1600s. See the discussion under *People* on page 4; see also the set of Survey Standards and Guidelines titled "Natural Disturbances in General" in White (2008*b*).

13. *The ecology of the state was in the process of undergoing substantial and unprecedented changes during the decades leading up to the so-called presettlement benchmark era, when the U.S. Public Land Survey was conducted.*

The first Europeans to live in Illinois were the French, who did not arrive until the late 1600s. By this time, intertribal warfare and newly introduced Old World diseases had already caused big shifts in the distribution and numbers of native people in the region. The French also induced major changes in the relationship between Indians and their environment by introducing new technologies and new economic factors.

Aside from transforming the indigenous human population of the region, the biggest impact of the French appears to have been the annihilation or near elimination of some large mammal species from substantial parts of the state. Bison appear to have been hunted virtually out of existence along the lower Mississippi River in Illinois within decades after the establishment of French settlements. Elk populations must have also suffered, but the extent of their decline is unknown. Perhaps white-tailed deer fared better — in part because their big wild predators, gray wolves and cougars, were disappearing before the French onslaught. Beaver probably were trapped out quickly from all but the most remote valleys. The French were not solely responsible for the decimation of wildlife: native Illinois people (as well as other tribes that moved into the area after the French) also killed off furbearers; they were abetted by Frenchmen who supplied guns, ammunition, and a market for the hides.

The European colonial era in Illinois was followed by a few decades of

transition before Native American title to the land was extinguished and English-speaking immigrants poured in to the region. Even before the Public Land Survey began, these new immigrants were already causing further changes in the vegetation and wildlife. "Squatters" had moved in and started farming, and they suppressed wildfires in order to protect their crops and homes. Up until that time, large areas had been maintained as grass and brush by a long history of repeated burning — but these areas began to grow up with trees as soon as the fires were halted.

In his 1836 *New Guide for Emigrants to the West*, J.M. Peck, a minister from St. Clair County, remarked about the rapid conversion of savanna and prairie to dense woods:

> When the fires are stopped, these barrens produce timber, at a rate of which no northern emigrant can have any just conception. . . . As soon as they are protected from the ravages of the annual fires, the more thrifty sprouts shoot forth, and in ten years are large enough for corn cribs and stables. . . . The rapidity with which the young growth pushes itself forward, without a single effort on the part of man to accelerate it, and the readiness with which the prairie becomes converted into thickets, and then into a forest of young timber, shows, that, in another generation, timber will not be wanting in any part of Illinois.

By the time crews from the Public Land Survey reached a particular part of the state, there often were already at least a few farmsteads in the area. The new residents may have already initiated significant changes in the local vegetation by altering the frequency, timing, and intensity of fires. The PLS documented the conditions that they encountered, which were often new and transitory. Was the brushiness of some of the savannas caused, in part, by trees newly sprouting up after farmers had put a stop to wildfires? Or were some areas becoming brushier because the new occupants of the land were killing trees when they burned off areas that had not seen such fires in the past?

Another set of uncertainties complicates efforts to understand the character of vegetation during the time of the Public Land Survey. What was the role of large grazing animals in shaping the vegetation? Populations of bison, beaver, elk, and deer underwent major changes during this era. Fluctuations in the numbers of large herbivores must have caused local changes in vegetation, but these impacts were almost never documented by early eyewitnesses.

14. *Even if Europeans had never come to America, the state's natural communities would have continued to evolve during the two centuries since the start of the Public Land Survey.*

If there is one essential trait of living organisms and natural communities, it is that they change. The ecosystems, plants, and animals that existed in Illinois during the 1700s and 1800s were determined in part by the climate at that time — but the ecology and biota were also the product of climatic conditions during the preceding hundreds of years. In addition, natural communities continually evolve even when the physical environment is stable. Although the climate of today is about the same as it was during the 1700s and 1800s, the distribution pattern of the vegetation would have changed since that time even if the state had not been appropriated by European immigrants.

The Public Land Survey provided a generalized picture of each township at a certain time in the past, but natural communities are dynamic. It would often be misguided to attempt to restore and maintain a site in the condition that the Public Land Survey documented.

I am reminded of an admonition that someone might hear when touring a commercialized "show" cave. The tour guide points out a foot-long stalactite and explains that it took 100,000 years to grow to that length. If the stalactite is broken, "It will take 100,000 years to grow back." In other words, "Don't break the cave formations. They take 'forever' to grow back." But this conservation message misses the point that the stalactite is likely to grow yet another foot longer in another thousand centuries if it remains unbroken. Our goal should not be to "restore" nature to some presumed static former state. Instead we should foster conditions that allow nature to continue to develop naturally.

15. *Today's environmental conditions are radically different from the past, so it is impossible to find "presettlement" conditions, or to restore a site to those conditions.*

Following is a summary of some of the pervasive changes in the ecology of Illinois:

Destruction and fragmentation of wildlands.—Most of the wildland in the state has been converted to farmland, reservoirs, and urban areas. This conversion has had profound effects on the ecology of the remaining wild areas. Relatively little natural habitat remains, and much of it is broken into small pieces, making it difficult or impossible for many plants and animals to disperse from one place to another. See the Survey Stand-

ards and Guidelines for habitat fragmentation in White (2008*b*).

Soil erosion and sedimentation.—Illinois farmland has lost about half of its topsoil since wholesale plowing and livestock grazing commenced in the 1800s. This soil has been deposited farther downslope and downstream in wetlands, lakes, and floodplains — forever altering conditions in lowlands.

Hydrology and water quality.—The watersheds of most natural areas have been largely converted to farms and towns. Water is polluted. Stream channels are likely to be dammed, ditched, and entrenched both upstream and downstream from a natural area. The state's big rivers have been highly modified for commercial navigation, and streams of all sizes are used to dispose of waste. Groundwater levels have generally been lowered. See the Survey Standards and Guidelines titled "Stream Entrenchment and Groundwater Depletion" in White (2008*b*).

Species composition.—Large native mammals are gone: bison, elk, wolf, black bear, and cougar. Hundreds of native plants and animals are endangered, and many other species are far rarer now than in the past. There has been a concomitant increase in generalist and opportunistic species (weeds and animal pests). In the absence of wild predators, white-tailed deer have become so abundant that they are severely damaging wild vegetation and affecting the survival and reproduction of other animal species (see "Deer Overabundance" in White 2008*b*). Stocking of sport fish has radically changed aquatic communities. Invasive exotic plants are taking over wetland and terrestrial ecosystems. Foreign disease pathogens are killing indigenous species.

Atmospheric conditions.—When Illinois was well vegetated and poorly drained, the local microclimate was generally more humid. The effects of global warming are now adding a new dimension to this issue.

In a 2005 essay about ecological restoration, Janisse Ray mused,

> Once we have shaped, controlled, and simplified the world — once we make the matrix depauperate — can we return places to the way they were?
>
> Can we get a landscape back? And what exactly is "back"?
>
> . . . What we find is that "back," once examined, may mean some static condition that never existed.
>
> However we imagine "back" to look, likely we won't ever reclaim

> degraded places to their undisrupted conditions. You see, when we alter the course of evolution, life doesn't necessarily continue on its merry way, even when we replace the biological elements that were removed. . . . Even when we replace all the pieces of a system, it will not return to what it would have been or even what it was.
>
> . . . So restoration may not be the attempt to revisit or re-create some mythical past or condition. More likely, restoration is the making of a new scenario, the creation of a new trajectory — not the original landscape, of course, but one more functional than a pine plantation, a field, a parking lot.

16. See the discussion of grubs in the Survey Standards and Guidelines for savanna (in White 2008*b*).

17. The phrase *natural heritage* was inspired by the use of the term *heritage* in the historic preservation movement. In the 1970s The Nature Conservancy adopted the term for its State Natural Heritage Programs.

18. A good introduction to this topic is *Bibliography of Repeat Photography for Evaluating Landscape Change* by Rogers *et al.* (1984).

    See the repeat photography of hill prairies in Volume 4 of the *Survey Standards and Guidelines* (White 2008*b*).

19. See the appendix titled "Historical Aerial Photography" in the *Survey Manual* (White 2008*a*).

20. The pros and cons of protecting small natural areas are discussed in the survey Standards and Guidelines for habitat fragmentation in White (2008*b*).

21. During the original Natural Areas Inventory in 1975–78, cemetery prairies were the only features that were systematically evaluated for their restoration potential (see Kerr and White 1981, which is reproduced in White 2008*b*). A total of 3,923 cemeteries were examined during this project. Twenty-four of these cemeteries had prairie and savanna remnants that qualified for listing as significant natural areas. In addition to these 24 cemeteries, 111 "notable areas" of disturbed prairie or savanna were identified in cemeteries. Thirty-five of these areas had high potential to be restored to high natural quality; 33 cemeteries were estimated to have medium potential, and 43 cemeteries had low potential.

22. The United Nations' Man and the Biosphere Programme has promoted the use of a three-level zoning system. In UNESCO's biosphere reserves, the

zones are termed the *core area*, *buffer zone*, and *transition area*; see <http://www.unesco.org/mab/mabProg.shtml>.

23. See the discussion of grazing in these two sets of Survey Standards and Guidelines: "Prairie" and "Grazing in Grassland" (in White 2008*b*).

24. See, for instance, studies by Bowles *et al.* (2003) and Bowles and Jones (2004, 2006).

25. This quotation is from White (1978:143–144).

APPENDIX:

MISSION AND GOALS FOR AN ECOLOGICAL RESERVE PROGRAM FOR ILLINOIS [*]

Mission of an Ecological Reserve Program for Illinois

The mission of Illinois' ecological reserve program will be to establish, maintain, and restore a system of protected areas that are sufficiently large, diverse, and numerous to fulfill the following goals:

- To encompass the broadest possible variety of natural ecosystems, natural communities, native species, and other natural features in Illinois.
- To allow ecological processes to operate as closely as possible to natural conditions.
- To maintain mosaics of natural communities and successional stages, with natural transitions among the various communities and stages.
- To support animals that require extensive areas and a variety of habitats.

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[*] Prepared for the Illinois Department of Conservation by John White of Ecological Services, Urbana, Illinois (1992).

- To help sustain native plant and animal populations by minimizing local extinctions and by fostering migration and colonization of native species.
- To provide habitat for animals that concentrate in dense populations when breeding, feeding, migrating, or overwintering.
- To protect aquatic systems by maintaining natural conditions to the extent possible within the drainage basin as well as downstream from the protected area.
- To restore natural ecosystems, and to apply and promote sustainable management and use of ecosystems.

Achieving these goals calls for a fresh approach to protecting and managing natural areas in Illinois. The ecological reserve program will entail procedures for selecting, designing, protecting, managing, and using natural areas and their surroundings so that the program's mission can be accomplished.

Definition of an Ecological Reserve

An **ecological reserve** is a site that contributes to the mission of the ecological reserve program by fulfilling one or more of the above-stated goals.

> *An ecological reserve is a large, diverse site that is protected and managed to maintain and restore natural ecosystems along with their ecological processes, natural communities, native species, and physical features.*

Several words in the above definition of an ecological reserve deserve elaboration. A reserve is a *protected* area in the sense that protection of the site's natural features is foremost; other purposes may be served by the site if these other uses are compatible with protecting the natural features for which the reserve has been established. A reserve must be *managed* to *maintain* and *restore* the area's natural features. Active management is necessary to ensure the survival of many native species and natural communities and to restore natural ecological processes. Because the landscape of Illinois has been so intensively exploited and altered, restoration efforts are necessary to meet the objective of maintaining natural diversity and fostering natural ecological processes.

Maintenance of natural diversity is a precept of the ecological reserve program. In the definition of an ecological reserve, this diversity is referred to in terms of "ecological processes, natural communities, native species, and physical features." Certain *ecological pro-*

cesses — particularly natural disturbances and biological activities such as predation and migration — are emphasized in ecological reserves because they often are key to maintaining natural diversity yet they often function well only on large areas. The second component of the definition, *natural communities*, are assemblages of plants and animals that share a common environment, as defined by the Illinois Natural Areas Inventory. [1] The state's list of *native species* includes animals and plants thought to have been present when Illinois was settled by human immigrants of European descent. [2] By definition, natural communities include only the *biotic* or living part of an ecosystem — in other words, biological species. The *physical features* in the definition of an ecological reserve consist of the *abiotic* or non-living environment (rocks, soils, waters, climate, etc.). All together, these living and non-living elements of natural diversity comprise *ecosystems*, which are the ultimate focus of the ecological reserve program. [3]

Explicit in the ecological reserve program is the concept of a *system* and a *network* of protected areas. Each site will be selected for the program on the basis of how the site will contribute to the overall mission of the program. Each ecological reserve will help meet at least one of the program's eight stated goals, and ecological reserves will be established specifically to meet these goals. Ecological reserves are part of a *system* because they are chosen to represent components of a systematic classification of the state's natural features (*e.g.*, natural communities, soils, and species). The reserves are part of a *network* in two senses. First, each reserve site can be considered a "building block" or a piece of the state's natural diversity; and second, the reserves serve as "stepping stones" for the movement of biota, linked to the extent possible by corridors of undeveloped land along which species can disperse.

Ecological reserves will be selected and designed so that each site encompasses as much of the local natural diversity as possible. The reserves will be as large as practical; because of the state's history of land use and ownership, most of the larger reserves will be on the scale of tens of square miles. An area of this size is likely to contain several hundreds of kinds of native vascular plants and vertebrate animals, in perhaps one or two dozen natural communities.

The manner in which ecological reserves are designed, managed, and used is as important in the long term as the way in which they are defined and chosen. Any large reserve is likely to involve several ownerships, various levels of protection, and a range of activities. [4] The entire reserve does not necessarily need to be strictly preserved: uses such as recreation and farming can be accommodated in a reserve outside the core natural area, provided that the uses are compatible with the goals of the ecological reserve program. The boundaries of a reserve *will* in fact need to be extended beyond the core natural area because adjacent activities have impacts on the natural area. These surrounding lands will need to be included within the reserve so that their use can be influenced in a manner that serves to buffer, enhance, or at least be compatible with maintaining the integrity of the natural area.

Because of the history of land use in Illinois, the ecological reserve program will involve *restoration* as a major effort. Ecological processes will need to be reintroduced; natural communities will need to be rehabilitated or reassembled; native plants and animals will need to be reestablished; and physical features will need to be reconstructed.

Goals for an Ecological Reserve Program

Goals for an ecological reserve program have been listed in the mission statement on pages A–1 and A–2. These goals can be stated in terms of eight topics:

Natural diversity
Ecological processes
Mosaics of natural communities and successional stages
Habitats for area-sensitive animals
Long-term survival of native species
Habitats for seasonal concentrations of animals
Aquatic systems
Ecosystem restoration and sustainable ecosystems

These topics serve as headings on the following pages.

Natural Diversity

GOAL: Ecological reserves will encompass the broadest possible variety of natural ecosystems, natural communities, native species, and other natural features in Illinois.

Preservation of natural diversity has been a linchpin of the natural area protection movement from the very beginning.[5] Natural diversity encompasses all aspects of an ecosystem, living as well as non-living. Over the past two decades there has been a tendency by many persons to equate "natural diversity" with "biological diversity" (or "biodiversity"), disregarding the non-biological part of nature. As this narrow assumption has gained acceptance, there has been a concomitant tendency among some conservationists to restrict attention even further — to "genetic diversity," ultimately at the level of subspecies and races.

A more holistic view of preserving nature encompasses a wide spectrum, which can be categorized in four levels: *genetic* diversity, *species* diversity, *community* diversity, and *landscape* diversity. The final level — landscape diversity — embraces complexes of natural communities. Landscape diversity also includes soils and other non-living components of

an ecosystem in addition to living species. *Natural diversity* encompasses more than *biodiversity*: it includes the non-living part of our natural world.

The goal of maintaining natural diversity must be achieved at two scales. At a site-specific scale, each reserve will contain as much of the local area's natural diversity as feasible. On a broader level, the system of reserves — taken as a whole — will encompass as much as possible of the full range of natural diversity in Illinois. Accomplishment of this goal calls for classification systems to help ensure that the state's natural ecosystems, natural communities, native species, and physical features are embraced in the ecological reserve system.

Ecological Processes

GOAL: Ecological reserves will allow ecological processes to operate as closely as possible to natural conditions.

Ecological processes consist of the biological and physical actions that shape and control an ecosystem. Here is a sampling of ecological processes and their effects on an ecosystem: (a) formation of soil by chemical weathering and decomposition of organic matter; (b) fixation of atmospheric nitrogen by bacteria in the roots of green plants; (c) changes in vegetation structure, microclimate, soil, and species composition through ecological succession; (d) control of animal populations by predators, diseases, and parasites, and (e) changes in natural communities that result from disturbances such as fires and floods.

Ecological processes are manifold and complex, and they operate at many scales, from the activities of one-celled organisms to geophysical forces that shape continents. Conservation biologists and natural area managers are not able to understand all of these ecological processes — much less to attempt to directly influence all of them. This inability may be just as well, for most processes carry on quite well without human participation.

Many ecosystems are able to function without human intervention, but actions by people were part of early Illinois ecosystems. Furthermore, recent human activities have drastically altered some of the basic processes that shaped the ecology of Illinois. Three examples illustrate this point. (1) Farming has fundamentally transformed the hydrology and quality of streams. (2) Because wildfires no longer sweep the plains, remnant grasslands, shrublands, and woodlands no longer experience the disturbance regimes with which they evolved and which they require for their continued existence. (3) Essentially all large predators have been eradicated, so the former balance of life — both animals and plants — has been changed dramatically. [6]

Because certain fundamental ecological processes have been drastically modified, the management of an ecological reserve must involve the restoration of these processes to the extent possible. To manage natural areas and to restore them toward their natural conditions, one must know which ecological processes once determined the character of the landscape. Two kinds of processes are most important to identify: (a) those which are most significant in maintaining the diversity of native species and natural communities, and (b) those which have been modified so much that the basic character of the natural ecosystem has been changed. Both kinds of processes need to be specifically addressed when designing and managing an ecological reserve.

Mosaics of Natural Communities and Successional Stages

GOAL: Ecological reserves will maintain mosaics of natural communities and successional stages, with natural transitions among the various communities and stages.

This goal is closely allied with the previous two goals. A healthy, diverse natural area has a wide range of natural communities in various stages of development. In a natural landscape, ecological processes along with the physical environment ultimately determine the distribution pattern of natural communities and their successional stages.

In early Illinois, patches of various natural communities shifted through time and space as they matured, often until they were returned to an earlier successional stage by disturbance. Repeated disturbances served to maintain early successional communities on sites that otherwise would have developed into later successional communities. As European emigrants and their descendants occupied Illinois, they wrought major changes that brought former disturbance regimes to a halt. For example, leveeing and damming of rivers stopped annual floods that had scoured and nourished the floodplains for millennia. Transformation of the prairie-scape into farmland halted the fires that rejuvenated prairies, maintained savannas, and favored oak woodland at the expense of forests dominated by maples. In the absence of disturbances such as floods and fires, the trend is toward a more homogeneous environment, lacking much of the state's former natural diversity.

Disturbances can maintain or increase the variety of habitats and species, but they can also eliminate species and entire natural communities, particularly on small remnant natural areas. An important consideration in the design and management of nature reserves is the effect of disturbances on the distribution and character of natural communities and on the survival of species — a field of conservation biology termed "patch dynamics."[7] In early Illinois, natural forces might have obliterated a particular patch of a natural community, but the community probably survived in neighboring patches, and it might reassemble in some fashion over time from plants and animals persisting outside the disturbed area. Under the present conditions in Illinois, many of the disturbance processes that maintained mosaics of

natural communities have been eliminated. Natural remnants are often very small and isolated from the sources of plants and animals that might recolonize a site after being eliminated by a disturbance; under these conditions, disturbances are likely to eliminate species rather than rejuvenate a community.

Natural diversity suffers greatly when the landscape no longer consists of a mosaic of natural communities, ecotones (transition zones), and successional stages among which animals and plants can migrate. A major aim of the ecological reserve program is to establish protected sites that are large enough to accommodate natural disturbances (and to reintroduce them where necessary and feasible) so that a natural mix of communities, habitats, and species can be maintained.

Habitats for Area-Sensitive Animals

GOAL: Ecological reserves will support animals that require extensive areas and a variety of habitats.

Many animals require different habitats during various periods of their life. During the course of a single day, an animal may need a variety of habitats to obtain food, water, and shelter. An individual may also need resources from distinctly different environments as it goes through its life cycle (for example, reproducing, migrating, and hibernating).

The largest predatory mammals and birds generally require the largest areas and range over the widest variety of habitats, but smaller animals sometimes require surprisingly large areas in relation to their size. Some insects, for example, may persist only on prairie remnants that are 100 acres or larger. [8]

In the past two decades, scientists have shown that many bird species need extensive blocks of natural habitat for breeding. [9] Extensive wooded tracts are necessary for the successful reproduction of many "forest-interior" bird species; cowbirds parasitize the nests of these songbirds, particularly if the nests are near the edge of the forest. Nests of both forest birds and grassland birds are also susceptible to destruction by raccoons and other predators that thrive along the edges between woods and open grasslands; nesting by these birds is more productive in large blocks of forest or grassland where predators are not as successful in finding nests.

Most common vertebrate animals survive on nature preserves that are of typical extent (on the order of 10 to 1,000 acres), and these animals often range from preserves onto adjacent unprotected habitat. The ecological reserve program will target species that require larger tracts than typical nature preserves. The size of many reserves will be defined in terms of

the acreage and habitat requirements of "area-sensitive" species such as raptors, river otters, and other wide-ranging carnivores.

Long-term Survival of Native Species

GOAL: Ecological reserves will help sustain native animal and plant populations by minimizing local extinctions and by fostering migration and colonization of native species.

Large, diverse, unfragmented reserves help ensure the long-term survival of wild species. Recent studies have repeatedly affirmed the importance of establishing large, intact, protected areas with a diversity of interconnected habitats. [10]

The previous goal addresses animals that require sizeable, diverse areas; many other species — including plants — need unbroken areas with a variety of environments if they are to survive indefinitely. For example, small vertebrates such as turtles need a variety of distinctly different habitats close together for feeding, resting, and breeding; these animals cannot travel far and they will not survive over generations if their home territory is too broken up with hostile environments such as cropland and roads.

In the immediate long term (over the next 50 to 200 years), ecological reserves are likely to become increasingly important for the survival of wild plants and animals in the almost-certain prospect of a globally changing climate. [11] The reserves will provide the unbroken habitat and the diversity of environments that will help make it possible for plants and animals to migrate in response to changes in the local microclimate. For instance, if the climate becomes warmer and drier as is predicted for Illinois, [12] some plant species may escape extinction by migrating down-slope over a period of years to a more sheltered site with higher soil moisture capacity — provided that the required habitat is not so isolated by developed land or other unsuitable habitat that the plant cannot reach it, and provided that the climate change is not too quick for the plant to keep pace.

Rapid changes in climate may have unprecedented effects on the distribution and survival of life on Earth. If the predicted changes come about, unprecedented efforts will be needed to forestall wholesale extinctions of sensitive species. Reserves of extensive, intact habitat — especially reserves with a diversity of topography and soils — will most likely prove necessary for the survival of many animals and plants.

Natural ecosystems are much more resilient to change where broad landscapes consist of unbroken natural areas. [13] Under such conditions, animals and plants are more apt to be able to disperse to new habitats in many directions, perhaps moving in a centuries-long wave-front across the landscape. The options for potential colonization sites are far more limited

in Illinois today, and the means of reaching these new habitats may be cut off by broad stretches of cropland and built-up areas. Corridors of wild land linking natural areas are proposed as a partial solution to this dilemma.

Habitats for Seasonal Concentrations of Animals

GOAL: Ecological reserves will provide habitat for animals that concentrate in dense populations when breeding, foraging, migrating, or overwintering.

Some ecological reserves can provide habitats which are essential for animals that gather in large numbers at specific areas during certain times of the year. For example, herons nest colonially in rookeries, and they depend on surrounding wetlands to produce food for their hungry nestlings. Amphibians and reptiles that are dispersed over hundreds of acres may migrate annually to ancestral breeding and denning sites for which there are no alternatives. Shorebirds depend on a sequence of stop-over sites during migration. Large numbers of certain bat species traditionally use a series of widely separated caves throughout the year: that is, as nursery colonies for females and young, as summer "bachelor" colonies, as late-summer roosts where they gather prior to migration, and as winter hibernacula.

By protecting seasonal concentration sites such as these, ecological reserves can contribute to the survival of animals that range across wide areas during other seasons. In this case the protected areas themselves may not be especially large, but they are critical to animals that range over very large areas. Because migratory animals require a series of sites, these seasonal concentration areas may be quite extensive when they are considered as a whole.

The approach of establishing integrated networks of protected sites is basic to the ecological reserve program. Such reserves may be compatible with areas that are managed for migratory game birds, but the ecological reserve system is intended primarily to protect non-game species.

Aquatic Systems

GOAL: Ecological reserves will protect aquatic systems by maintaining natural conditions to the extent possible within the drainage basin as well as downstream from the protected area.

Groundwaters and surface waters fall under the scope of the first goal, "natural diversity," and waters are part of every other goal — but aquatic systems need to be singled out with their own goal because they may not otherwise receive the attention due to them.

Effective protection of aquatic systems requires that far more than water be protected. Streams pass through numerous ownerships, and their watersheds encompass many times more properties. Lakes pose their own challenges for protection, and they are vulnerable to much the same impacts as flowing waters. Both lakes and streams are maintained in part by subsurface waters, which have unique problems when considered from the standpoint of protection.

Surface waters are the focus of many activities and uses. These waters are used for transportation, recreation, and waste disposal. Their natural resources are harvested commercially and for personal use. Their banks are favored sites for towns, highways, railroads, and utilities; floodplains are leveed, drained, and farmed. Lakes and streams receive soil and chemical pollutants from their floodplains and tributaries. Aquatic natural communities have been radically altered by the introduction of non-native fishes.

Groundwater is hidden but is not separated from the surface and the world of human activities. Water beneath the earth can be depleted and polluted; such damage can be quite slow, difficult, and expensive to remedy. This damage has an impact on underground ecosystems, and it affects the surface ecology when the groundwater reemerges in seeps, springs, lakes, streams, and wells.

Compared with terrestrial and wetland natural communities, aquatic natural communities generally enjoy less attention from biologists and nature preservationists. Most aquatic animals are hidden and not as easily studied as terrestrial forms; most botanists do not study open waters because these areas lack vegetation. Yet Illinois has a tremendous variety of aquatic organisms, including many of our most endangered species. Twelve species of mussels were recently removed from the list of endangered species in Illinois because no living specimens have been found for years, and these species are now thought to be extirpated. Now almost all native mussels are in serious jeopardy from invasion by the European zebra mussel.

An aquatic habitat may be affected by activities anywhere within its drainage basin — even downstream from the area that is being protected: for instance, a dam below a protected segment of a river will stop or hinder the migration of fish to and from the protected area. As another example, channelization of the lower Cache River is causing channel entrenchment and severe erosion in a nature preserve miles upstream from the part of the Cache that has been channelized.

The special attributes of aquatic ecosystems make protection of waters challenging — and call for approaches that have not traditionally been applied to non-aquatic areas. Reserves that do a good job of protecting aquatic life usually will need to be quite extensive because the entire drainage basin ideally should be afforded some level of protection. Some eco-

logical reserves should be established specifically to protect aquatic systems, but water is basic to the ecology of every ecosystem.

Ecosystem Restoration and Sustainable Ecosystems

GOAL: Ecological reserves will restore natural ecosystems, and will apply and promote sustainable management and use of ecosystems.

All other goals of the ecological reserve program depend on this final goal. Natural conditions need to be restored to ensure that the goals of maintaining natural diversity and ecological processes are achieved. The entire program depends on the maintenance of sustainable ecosystems in the long term, both in the core protected area as well as on adjacent land that is not strictly protected.

Ecosystem sustainability has become a catch-phrase for the conservation movement. This interest has arisen along with the recognition that protected areas are not viable in the long term unless the surrounding land is used in a conservation-minded manner, in which the natural resources can be sustained indefinitely. The majority of land around potential ecological reserves in Illinois is farmed, so sustainable agricultural methods will be key to the ecological reserve program. Ecological reserves will serve as experimental areas and models for developing sustainable and compatible land uses.

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Endnotes for the Appendix

1. See "Classification of Natural Communities in Illinois," developed for the Illinois Natural Areas Inventory by White and Madany (1978). *Native* natural communities — which are dominated by native species and are not created or directly maintained by human activities — are the focus of the ecological reserve program. The Natural Areas Inventory classification also addresses "cultural" natural communities such as cropland and developed land; however, in the context of the ecological reserve program, *natural communities* are implicitly native natural communities unless otherwise stated. The continued existence of many of Illinois' natural communities requires periodic burning; these communities have evolved along with repeated fires set by people for centuries. Such fire-maintained communities are considered native natural communities even though they require human-set fires for their maintenance.

2. Common species as well as endangered and threatened species fall under the purview of the ecological reserve program. The program will focus primarily on vascular plants and vertebrate animals at the outset because the taxonomy and distribution of these species are rather well known. By protecting many large areas with a diversity of natural communities, the myriad smaller, cryptic, and poorly known life forms will also receive some degree of protection, yet many rare invertebrate animals, non-vascular plants, fungi, and other small organisms are likely to become extinct without our even knowing about them. (For the purposes of this discussion, all forms of life are considered to be either plants or animals even though several other kingdoms of life are now recognized by biologists.)

3. An ecosystem is defined in terms of three components: (1) an assemblage of plants and animals, (2) their physical environment, and (3) the interactions among the species and with their environment.

4. *Examples of ownership of ecological reserves*: local government, private individual, and business corporation. *Examples of protection*: conservation easement, dedicated Illinois Nature Preserve, Natural Heritage Landmark, management agreement, and informal commitment. *Examples of uses*: nature preservation, farming, scientific research, and recreation.

5. Landmark discussions of the importance of preserving natural areas and natural diversity are in writings by Victor Shelford (1926), George Fell and others (1972), and E.O. Wilson (1988).

6. An example regarding white-tailed deer serves to illustrate how a change in an ecological process — in this case, *predation* — can have far-reaching effects.

Because Illinois no longer has the large carnivores that preyed on white-tailed deer, the deer have become overly abundant, especially in the region surrounding Chicago where hunting is banned or severely restricted (see Ambrose 1992). The overabundant deer are depleting the woodland herb layer and are damaging the woody understory in Busse Forest Nature Preserve (Cook County), Ryerson Conservation Area (Lake County), and many other forest preserves. Uncontrolled numbers of deer are causing the local extinction of certain wildflowers; the species composition of trees and shrubs is also changing as plants that are favored as food by deer fail to reproduce. For an introduction to the literature on the impacts of high populations of deer on natural areas, see Miller, Bratton, and Hadidian (1992) and the articles that they cited.

7. The concept of "patch dynamics" has gained wide acceptance in conservation biology. A 1978 article by two University of Illinois students, Steward Pickett and John Thompson, is widely recognized as the pioneering paper on the subject.

8. See Panzer (1988, 1991).

9. See Robinson (1991) and Wilcove and Robinson (1991).

10. See Shafer (1990) and Harris (1984).

11. See Wyman (1991).

12. For further information on the possible future effects of global warming on Illinois, see the 1991 report by the Global Climate Change Program of the Illinois State Water Survey.

13. Three hundred years ago, Illinois was one natural area of 36 million acres on the shore of *Lac des Ilinois* (Lake Michigan); in 1978 the count was 25,723 acres of high quality natural communities in 610 natural areas (White 1978).