

# Horizon 2100



WHAT IT COULD BE

AGGRESSIVE CONSERVATION FOR  
NORTH CAROLINA'S FUTURE



e

ENVIRONMENTAL DEFENSE

finding the ways that work



CITY OF RALEIGH PARKS AND RECREATION DEPT.



BILL LEA

THE FUTURE OF CONSERVATION—AND THE POSSIBILITIES FOR HUMAN ENTERPRISE—REST ON THE SUCCESSFUL INTEGRATION OF THE NATURAL AND HUMAN ENVIRONMENTS.

FRONT COVER PHOTOGRAPHS AND PAGE 2/3 BACKGROUND PHOTOGRAPH: DERRICK HAMRICK



DERRICK HAMRICK

## HORIZON 2100

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## THE CHALLENGE TO THE NEXT “GREATEST GENERATION”

**T**hey have been called America’s greatest generation: our parents and grandparents who courageously endured untold horrors and overcame the menace that in the mid-twentieth century threatened to deprive future generations of political freedom. Fortunately, that generation had the vision and the sense of responsibility to meet such challenges and build a way of life that has given subsequent generations the freedom to create and pursue their own destinies. Today, current generations face a comparable challenge: to conserve and protect the freedoms provided by a clean, healthy, and natural environment.

Although not so obvious as the threats to political freedom, the threats to the natural environment are perhaps even more confounding and challenging as they usually are the product of our own, sometimes witless, design. Yet this much is clear: a degraded environment can deprive people of life, liberty, and the pursuit of happiness as surely as a malevolent dictator. An unhealthy environment will subject future generations to a tyranny of ecological crises, for only a healthy environment can provide the choices and opportunities on which a free society and a healthy economy are based.

In meeting their challenges, that “greatest generation” could not guarantee the future, but they could and did provide the basis for hope. Similarly, the conservation decisions and policies of current generations will greatly influence tomorrow’s environment, and they can leave a legacy of hope – or one of despair. Today’s North Carolinians can rise to the challenge, preserving a different kind of freedom. To begin, they can cultivate a vision of a future society in which people will be relatively free from the domination of ecological crises and are able to relish the economic, aesthetic, and spirit-sustaining benefits of a healthy environment.

*“Without vision,*  
**E**nvironmental Defense asked nine of the state’s leading conservation scientists to create just such a vision of the healthiest, most natural environment that North Carolina could have in 100 years. Their answer, HORIZON 2100, is not just another plea for conservation; instead it describes and points the way to a desirable and attainable destiny for the people and natural heritage of North Carolina.

Looking forward from the threshold of the twenty-first century is both invigorating and intimidating. It is invigorating because four decades of increasing environmental awareness have led to impressive conservation successes and a foundation for even greater progress in the future. It is intimidating because the price for not taking advantage of these opportunities will be high. North Carolina will experience profound and perhaps irrevocable ecological losses over the next three to four decades unless human activity begins to attend more carefully to the needs of natural systems.

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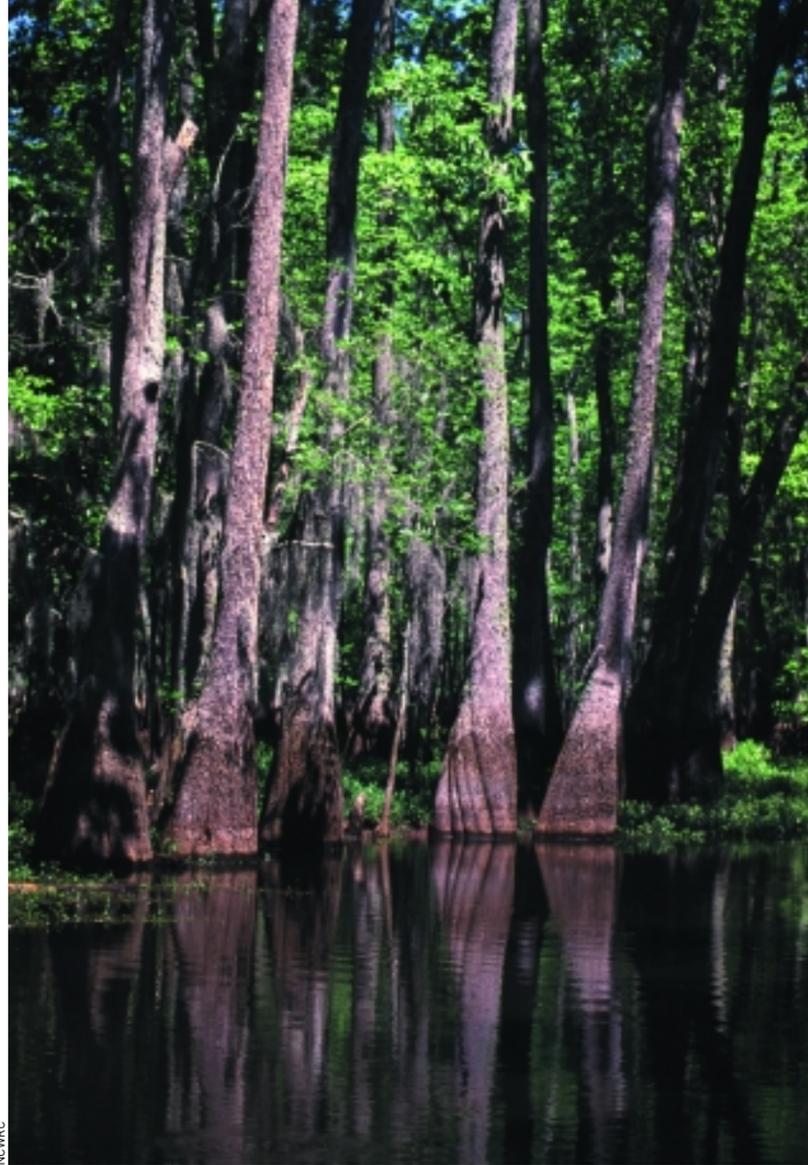
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**WHAT it COULD BE!** What will successful aggressive conservation look like? A selection of visionary glimpses of restored rivers, mountains, meadows, and more tell the compelling story of a possible legacy of wonder.

**9, 11, 17, 25, 33**

*the people will perish.”*

Proverbs 29:18



NORTH CAROLINA IS STILL HOME TO AN ASTONISHING ARRAY OF WILD PLACES SUCH AS THIS CYPRESS SWAMP.

Beyond the cities, streams and rivers, cleaned of municipal and industrial waste and stormwater runoff, tumble and meander through a verdant countryside. Every day is a clean-air day, and from 30 miles away you can see the swell of the Blue Ridge Mountains. Along the Atlantic Ocean, beachcombers, fishermen, and shorebirds enjoy wide and natural beaches, unimpeded by the seawalls, bulkheads, and jetties that have stolen so much of the nation's coastline.

Home to perhaps 16 million people—twice the current population—this future North Carolina also offers a landscape inhabited by restored populations of native wildlife. Skies are again filled with flocks of canvasback ducks, and meadows are flecked with Bachman's sparrows. Coastal rivers teem with tens of millions of sturgeon, American shad, and river herring. Estuaries are fringed with marsh and filled with scallop beds and

oyster reefs. Mountain creeks once again glitter with gilt darters, and Piedmont rivers are home to healthy schools of migrating robust redhorse. Picture a North Carolina known for its glorious natural areas, large enough and wild enough to harbor large, mobile mammals, as well as backpackers and paddlers.

That is one vision; here is another: Think of North Carolina beaches cluttered with high-rise buildings where waves lap against mile after mile of ugly, sandbagged seawall. Sounds are littered with signposted warnings: Do Not Swim. Do Not Wade. Contaminated: Do Not Harvest Shellfish. A rolling Piedmont is cluttered with unbroken suburbia from Charlotte to Rocky Mount. Water shortages plague most of the state, and foul air frequently forces the young and the old indoors. Mute woodlands stand bereft of wildlife and robbed of diversity, and mountain forests are denuded by insects and

acid rain. Once-healthy mountain streams are so choked with sediment that North Carolina's native trout now must be protected as a threatened species. After years of unmanaged growth, sprawl, and insufficient attention to nature's needs, the few and isolated pockets of public open space are overwhelmed by hordes of people escaping the oppressive living conditions of the urban centers. And fragmented, overused wildlands—stripped of native predators, diversity, or even much hope—are hardly wild at all.

Neither of these contrasting visions is as implausible as it may at first seem. Each is a possible scenario describing the landscape, environment, and natural heritage that future generations of North Carolinians may inherit in 2100. The first inspiring and appealing scenario envisions the North Carolina environment that would likely result from 100 years of bold and comprehensive conservation, if begun today. It is called HORIZON 2100. The second bleak description envisions what will likely result from continued sprawl and unmanaged growth. Indeed, it is not the worst-case scenario but a future predictably arrived at from North Carolina's current

trajectories of haphazard development, softened only by well-intended but insufficient conservation strategies.

Because the fate of the state is not set in stone, the choices made today regarding human activity and conservation will largely shape its natural environment in 2100. The human species has an unprecedented



GREEN TREEFROG

ability to influence—for better or worse—the structure and function of nature. How current and subsequent generations choose to wield this influence will determine the possibilities for generations yet unborn. By 2100, the natural environment of North Carolina may

“A bold vision of what is possible can help North Carolinians build a healthy tomorrow.”



MELISSA MCGAW

A HEALTHY ENVIRONMENT IS A WONDERFUL LEGACY TO LEAVE OUR CHILDREN'S CHILDREN.

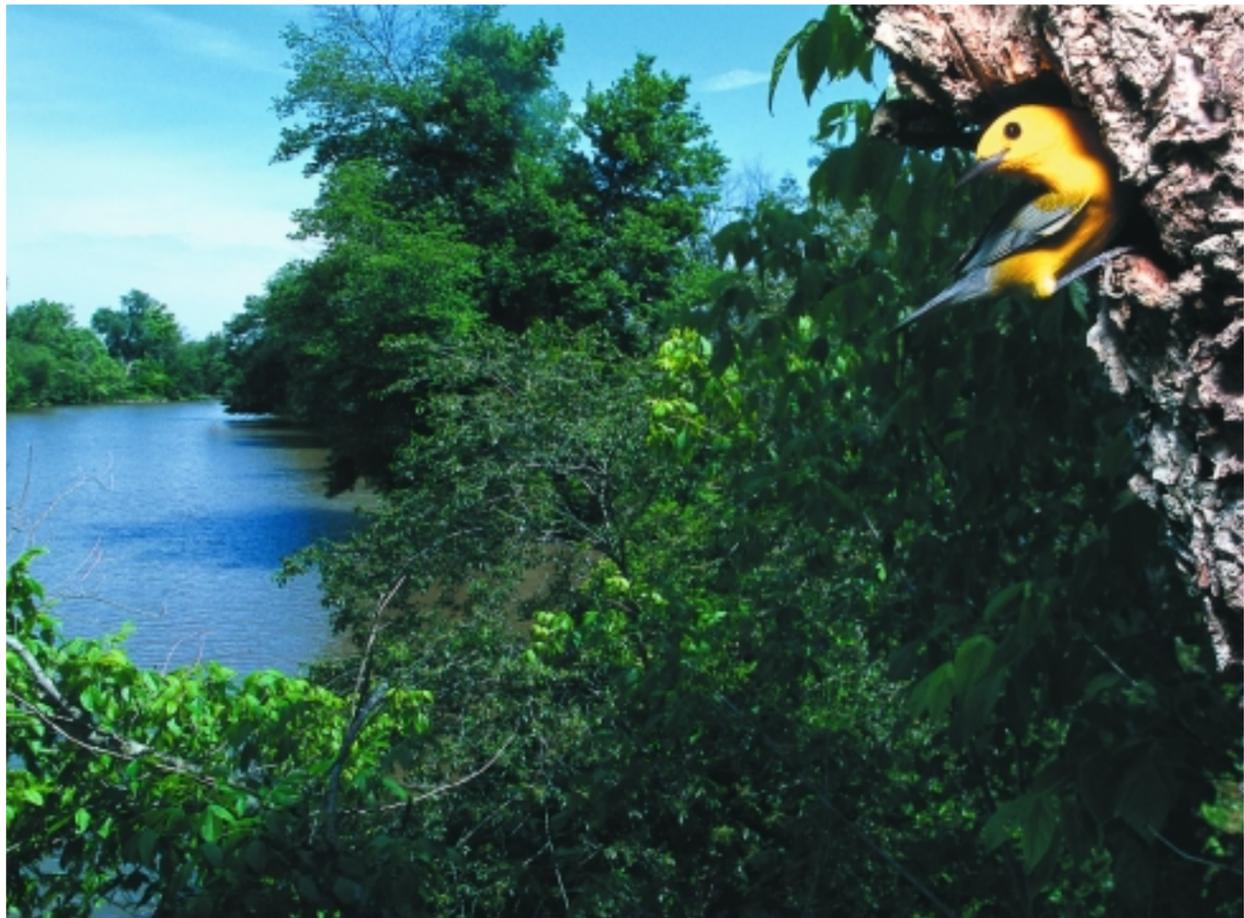
provide a home in which our children and grandchildren thrive, much as we have in our lifetimes. Or the environment may be so impoverished by centuries of casual neglect that our heirs must struggle simply to survive. The future begins with the decisions made today.

A bold and inspiring vision of what is possible can help North Carolinians build a healthy tomorrow. Future conservation will be better integrated, more universally understood and supported—and vastly more successful—if it is informed and inspired by a clear vision of the North Carolina environment that can result from aggressive conservation. The science of ecology and an understanding of the complex natural systems that comprise our home are the proper starting points from which to construct such a vision.

## SEEING is BELIEVING

Picture a North Carolina that is once again home to expansive Piedmont prairies and coastal savannas, to healthy mountain bogs and hardwood bottomland swamps. Imagine a restored landscape where vast stands of longleaf pine cloak the Coastal Plain and majestic chestnut forests reclaim ridge after mountain ridge. In this future North Carolina, people and nature thrive together. Cities and towns, more populous than ever before, are clean, vibrant, comfortable, and secure. Efficient transportation and smarter use of energy and water resources make life healthier and safer. Carefully managed green spaces and wild things flourishing in the urban heart nurture the human spirit. City residents frequent greenways and parks, which also support throngs of migrating songbirds and small mammals that leave their tracks along the streams. Public, private, and corporate open lands are fine-tuned to provide wildlife habitat and water- and air-cleansing greenery. Even small backyards add to the natural fabric of this vibrant picture.

A PROTHONOTARY  
WARBLER CASTS A  
GLANCE ACROSS ITS  
NEUSE RIVER HOME.



DERRICK HAMRICK

### BUILDING a VISION

HORIZON 2100 is the product of more than a year's collaboration among some of the state's leading conservation thinkers. A panel of nine of North Carolina's most eminent ecologists envisioned a future North Carolina environment in which the most comprehensive, biologically rich, integrated, and functional native ecosystems were conserved and restored at appropriate scales, while ensuring a high quality of life for a growing human population. With both the knowledge and the liberty to contemplate the ecological possibilities, the panel offers this "shining light" description of what can be achieved through comprehensive and aggressive conservation.

HORIZON 2100 is built on principles supported by scores of other environmental scientists. It reflects the public's growing desire for more comprehensive and forward-thinking conservation of North Carolina's natural environment.

HORIZON 2100 is also informed by a strong appreciation for inevitable demographic, economic, and climatic trends, but is not constrained by shortsighted social or political ambitions. It provides a reasonable vision of a productive and healthy North Carolina a century into the future. It also points the way to a North Carolina in which our children's grandchildren can drink clean water

and breathe clean air—in which people can make a living and yet still live amid natural splendor.

For too long, conservation has been misunderstood as a longing to recreate some idyllic or imagined pristine condition of the past, or as a desperate clinging to some freeze-framed preservation of the nature we know today. HORIZON 2100 does not seek to recreate what once was, but to allow the natural evolution of the best that still can be. In creating HORIZON 2100, the ecologists looked at the big picture and asked critical questions:

- Given what remains of North Carolina's natural fabric, what needs to be done to ensure that the environment a century from today will provide a similarly high quality of life?
- Given what is known about natural succession and the restorative powers of inspired conservation, what are the best opportunities to restore natural systems, rebuild populations of native wildlife, and knit human populations and ecosystems into a viable, vital fabric?
- Given the impending changes in population and climate, what is the best path to the new and different landscapes that will provide a suitable environment for future North Carolinians?

“HORIZON 2100 does not  
seek to recreate what  
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**natural evolution**  
of the **best that still can be.**”

In response, HORIZON 2100 offers a compelling picture of and pathway to the best natural landscape to which North Carolina can aspire. This vision contends that intelligent conservation, informed by both what exists in North Carolina today and what natural succession and active restoration could produce in the future, can yield spectacular results. But fulfilling the promise of HORIZON 2100 will require that the policies and patterns guiding the state's conservation efforts be swiftly and fundamentally altered. Continuing the recent trends of piecemeal conservation and diluted environmental policies will result in a North Carolina that is far less healthy, vital, and prosperous than the state that science tells us is attainable. Moreover, the time to change the state's conservation strategies is short; what is possible today will not be so for long. In less than a single generation, a sprawling population is likely to deprive North Carolina of many of today's conservation opportunities.

TINY WATERWAYS  
GIVE ENTRY TO VAST  
WILDLANDS IN THE  
COASTAL PLAIN.



T. EDWARD NICKENS

STRIPED BASS RESTORATION IN THE ROANOKE RIVER IS PROOF OF NATURE'S HEALING RESILIENCE.

## NORTH CAROLINA TODAY and BEYOND

The first step in contemplating the future of North Carolina's landscape is to understand where it is today.

North Carolinians have been blessed. From magnificent mountains to fertile farmlands, from vibrant tide-water plains to productive estuaries and oceans, truly marvelous natural systems have enabled North Carolinians to enjoy happy, healthy, and prosperous lives. Yet no North Carolinian will ever again experience the wonder of looking up to a sky darkened by passenger pigeons or see a flock of Carolina parakeets. The once expansive vistas of the Outer Banks and the Blue Ridge are already sullied by sprawling development. HORIZON 2100 accepts that the existing footprint of human infrastructure, including highways, cities, and sprawl, will not diminish but will continue to expand in the near future, adversely affecting the state's ecosystems and the benefits and services that those ecosystems provide.

Some change is inevitable; but many of the changes caused by human activity are undesirable and can be avoided or more thoughtfully managed. At the beginning of the twenty-first century, we have inherited an increasingly urbanized state in which the natural landscape is severely fragmented, the quality of the air and water is diminished, and many native plants and animals are under siege. All of these realities indicate the need for more aggressive conservation.

For much of the twentieth century, people moved out of North Carolina to other places, but in the 1970s that trend reversed. Ever since, the state's population has continued to grow, largely because of in-migration. With this recent growth, North Carolina lost more productive



DOUG STAMM/stammphoto.com

farmland and forestland to development between 1992 and 1997 than did all but three other states. In addition, more and more of its native forests have been converted into intensively managed pine plantations. In the southern Coastal Plain alone, pine plantations cover a land area more than twice the size of the Great Smoky Mountains National Park. Over the last twenty years, these pressures have pushed many conservation efforts into piecemeal or opportunistic actions. That is, patches of land are targeted for conservation not because they have significant ecological value but because they offer some immediate scenic or recreational value. Certainly, ecological objectives can be more easily achieved on carefully managed farms or timberlands than on developed landscapes, but the real challenge is to coordinate conservation so that an environmentally functional mosaic is restored and maintained across the landscape. The new model of conservation suggests that productive, well-managed, working lands need not fragment the natural environment but, rather, can be functionally integrated as a complement to preservation areas.

More than woods and wildlife are at stake. Clean air and water are vital to basic human health; they are also the natural capital of a healthy economy. The atmosphere has a limited assimilative capacity to absorb

INTENSIVE FARM AND FOREST MANAGEMENT AND URBAN SPRAWL CAN DESTROY AND FRAGMENT NATURAL ECOSYSTEMS.

## WHAT IT COULD BE!

If North Carolina fully commits to aggressive conservation, the state's landscape in 2100 will be vastly different from what it will be without such a commitment. HORIZON 2100 will take North Carolina to a very different destination than the trajectory of current trends and policies. The following segments offer a glimpse of what a conserved environment might offer to 16 million North Carolinians in 2100.

### THEY'RE in the RIVER

They're in the river before the shadbush blooms on the banks of the Haw, before the dogwood leaves are the size of a squirrel's ear: that's what the old fishermen would say. The fish come with the earliest hint of spring—pulsing up the Cape Fear and the New, the Neuse, Tar, Pamlico, Roanoke, Cashie, and Chowan. They surge up the main channels and spill into the tributaries—Pitchkettle and Wheat Swamp and Jericho Run and Reedy and Turnpike Branch and Cutawhiske and uncountable tiny rivulets that quiver and ripple with their millions. Come spring, they come from the sea, and they come in numbers unknown since corned herring was the common lunch of every farmer who rode a plow behind a mule.

A century of fixing North Carolina rivers has brought the river migrants home. For the state's eight species of anadromous fish—Atlantic and shortnose sturgeon, hickory and American shad, striped bass, sea lamprey, blueback herring, and alewife—the waterways of 2100 seem more like the streams of 1800 than the dammed, befouled, overfished rivers of 2003. And now the fish gush through tidal estuary and cypress-clad Coastal Plain, through rapids where the rivers roil over the Piedmont fall line, nosing ever upstream to spawning grounds tens, scores, hundreds of miles from the sea. How many fish migrate up North Carolina's rivers in the restored runs of 2100 is anyone's guess, but there is agreement on this: They come in numbers that North Carolinians could hardly have dreamed just 100 years earlier.

In the Neuse, hundreds of thousands of American shad swim over the rubble remains of the Quaker Neck Dam near Goldsboro, the first dam to fall in North Carolina for the sake of fish. In the Cape Fear River, the big shad—some grow to eight pounds or more—skirt Lock and Dam No. 1 through a half-mile-long canal designed specifically for fish. The population took off after the bypass was built and exploded after the remaining two locks were removed, giving the metallic green-blue fish access to their primary spawning grounds near Erwin for the first time in who knows how many generations of shad. Buckhorn Dam is a nuisance, to be sure, but outfitted with fish ladders, it is not an insurmountable obstacle, and the spawning grounds of the Deep and the Haw lie just above. In the late 1800s, the commercial harvest of American shad topped 700,000 pounds per year in the Neuse alone. Now these two rivers draw thousands of anglers drifting bright-colored shad darts for a half-million migrating fish.

The story is the same in North Carolina rivers from the Pee Dee to the Pasquotank: Through sustainable harvest initiatives, fish-friendly dam engineering, and dam removals, North Carolina's runs of anadromous fish dwarf anything within the memory of a living human. American shad and stripers in the Roanoke crowd the elevator-like water lifts that raise tens of thousands of fish each year above the Roanoke Rapids Dam and Kerr Lake Dam, giving them access to the Dan and Staunton Rivers. Striped bass in the Neuse are so numerous that the splashing, violent "rock fights" of spawning bass churn the Neuse for a half-mile below the Falls of the Neuse Dam tailrace. Hickory shad ascend Blewett Falls Dam on the Pee Dee River and strike out for the rocky rapids of the Uwharrie Mountains. Each year 20,000 Atlantic sturgeon—six-foot-long primitive beasts—migrate from Albemarle Sound into the Roanoke River. They are common sights in the Roanoke River rapids on the outskirts of Weldon.

And then there are the river herring, denizens not only of the mainstem rivers but also of every feeder stream, swamp creek, and drainage ditch in the watersheds of Albemarle and Pamlico Sounds. Once they were in the water by the millions: in a single year, 20 million pounds of alewives and blueback herrings would be netted in Albemarle Sound alone. "They would come in like droves of blackbirds," said an old man in 1990, remembering the days of his youth. And in 2100 they do once again. They throng into millponds and cypress swamps. Acres of water ripple and writhe as the fish lay their adhesive eggs on cypress roots and knees. No one can remember when there were more fish.

They're in the river again—shad and striped bass, herring and eel—and so are the fishermen. Long forgotten are the bitter fights over shorter and shorter seasons, smaller and smaller quotas. The fish are back, and so are the fishermen—the families who fish for a living, who fish for fun, who fish for tomorrow's supper. For too many years, North Carolinians had forgotten what a river could be. The fish, by their thronging, strident, restored millions, have restored in the people a vision of the possible.

WHAT IT COULD BE IN 2100



PAUL NURNBERG



NC DOT

“More than woods and wildlife are at stake. Clean air and water are **vital** to human health, and they are the natural capital of a **healthy economy.**”

pollution, and our ground and surface water supplies are not infinite. Learning to live comfortably within very real limits—and determining what level of use and degradation of air and water is compatible with conservation goals—poses a major challenge for North Carolina over the next century. Consistently, North Carolina’s air quality ranks among the worst in the nation. Every year, polluted air triggers hundreds of thousands of asthma attacks in North Carolina and causes more than an estimated 1,800 premature deaths. North Carolina’s lakes and rivers are choked with sediment, and once healthy estuaries are overloaded with nutrients. Hundreds of miles of North Carolina’s rivers and streams and sounds are so polluted that they do not meet minimum water quality standards.

It is a matter not only of water quality but also water quantity. Recent years of drought coupled with the anticipated effects of global warming should be sufficient warning to halt a history of the casual disregard with which North Carolinians have used surface and ground water. In certain regions of the state, most notably the central Coastal Plain, groundwater has been withdrawn far faster than it can naturally recharge, leading to shortages that impose stiff environmental and economic costs on local communities.

Fragmentation of the landscape, diminished air and water quality, alteration of hydrology, extermination of predator species, and other disturbances of habitat adversely effect plant and animal populations, which in turn further erode the overall health and vitality of natural systems. Today, 700 of the state’s more than

A LACK OF VISION PRODUCES A LEGACY OF DENUDED LANDSCAPES AND FOULED STREAMS.



NCWRC



NCWRC

4,000 plant species are considered rare or extremely rare. Many other once-prolific plant species now survive only in very limited ranges. Most plants, rare or otherwise, are integral parts of natural communities and require more intact habitat than the relict scraps of land that mere chance has left available.

Direct destruction by the plow, bulldozer, and chain-saw has taken a toll, but another human factor has also had dramatic impacts on the state’s plant communities: the suppression of naturally occurring fire. Many of the state’s natural plant communities are dependent, to one degree or another, on a natural fire regime. Longleaf pine forest typically burned at least once every three to five years. Now this once-dominant forest type in eastern and central North Carolina has been reduced to 3 percent of its native range. Atlantic white cedar and natural cane-brake communities, both of which rely on periodic fire, currently occupy less than 1 percent of their former ranges.

Animals, too, have lost refuge in this increasingly human-dominated landscape. Virtually every grouping of species, from mammals to birds, fish, reptiles, amphibians, and invertebrates, has been reduced in diversity and sheer numbers by human exploitation, habitat fragmentation and degradation, pollution, loss of top predators, and invasions by exotic species. The rate of decline of animal diversity and populations has accelerated in the last 150 years. Today more than one-fifth of North Carolina’s native mammal species are designated as rare and in need of special protection. The same applies to more than one-quarter of the bird species, more than one-fifth of the butterfly species, more than one-third of all reptiles, one-quarter of freshwater fishes, and three out of four freshwater mussels. North Carolina has the greatest diversity of amphibian species in the United States, but almost one-quarter are at risk. Even the venerable bobwhite quail is the object of a last-ditch,

CONTROLLED BURNING NOW REPLACES NATURAL, PERIODIC FIRE—AND ALLOWS FORESTS, MARSH, AND OPEN MEADOWS TO FLOURISH ANEW.

\$5 million conservation effort. That so many species have been reduced to precariously low numbers is a warning that all is not well. Further extinctions of native species are not merely likely but inevitable unless a concerted effort is made to provide conditions in North Carolina that will be congenial to nature as well as the human occupants of the state.

While the dramatic loss of biodiversity is a worldwide problem, conservation is ultimately a local activity. But North Carolina has not yet made the commitment needed to save and restore its natural heritage. In sharp contrast, Virginia’s Natural Heritage Program employs

approximately four times the staff as North Carolina’s does. Furthermore, much of contemporary conservation is dedicated to the vague objective of preserving open spaces rather than conserving ecological function and biodiversity. Counting on a patchwork of nature preserves and “green spaces” to provide full ecosystem benefits is not realistic, nor is it possible to manage the entire North Carolina ecosystem on only a small fraction of the landscape. Alternatively, a comprehensive conservation strategy that fosters better management and stewardship of virtually all the land in North Carolina, both private and public, can be both realistic and very effective.

## THE VIEW from COLD MOUNTAIN

WHAT IT COULD BE IN 2100



T. EDWARD NICKENS

It is early autumn, the morning of the season’s first frost, and the bugling of an elk off Cold Mountain’s southern shoulder halts two backpackers in their tracks. The bull is a mile away, in the big timber cloaking Ugly Creek, but still its eerie, urgent bellow rolls across the great vernal sweep of the Great Balsams Core Reserve.

The hikers turn toward the sound, mesmerized. They have walked to Cold Mountain from the Shining Rock Wilderness a dozen times, but this is the first time they’ve heard the bugle of a rutting elk, just as the night before was the first time they’d heard the wolves.

It is early autumn in the year 2100, and the burnished red leaves of American chestnut clatter in the wind. The Southern Appalachian’s hemlocks are gone, along with the balsams, both victims of nonnative insect outbreaks that peaked 60 years earlier. But the glorious chestnuts are back, transplanted from blight-resistant rootstock and crossed with Asian varieties. Now 50 years old, the trees are quickly marching toward the ridgelines from the restoration groves on Cold Mountain’s lower flanks.

The shadows grow long, and the hikers continue to climb toward Cold Mountain, its 6,030-foot peak dominating the Great Balsams Core Reserve. The reserve’s 80,000 acres link Pisgah National Forest to the Great Smoky Mountains National Park through the Plott Balsam-and-Cowee Corridor. That’s where the elk came from, 30 years ago, migrating from the Cataloochee elk restoration project area. The Smokies, too, nursed the first generation of mountain lions, and not long ago a rock climber on the trail to Devil’s Courthouse reported the second sighting of a big cat south of the Smokies.

The hikers stop to chat with a grouse hunter who sends a wag-tailed setter into the brush of a small, recent timber cut. Six months ago, golden-winged warblers flocked to the cut’s fire cherry and maple scrub. Now grouse and turkey vie for the fox grapes that vein the edges. Small timber harvest plots ring the reserve’s core ecological preserve zone, providing for wildlife as diverse as neotropical migrating songbirds, bear, and recently reintroduced fisher.

From their camp on top of Cold Mountain, the backpackers can see the glittering plain of lights to the north and east that mark Waynesville, Asheville, and Hendersonville, long since merged into a sprawling municipality of a million residents. But to the south a dark crescent unfurls for miles. That’s where the next generations of elk and wolves and fishers will go: beyond the Great Balsams, along the corridors that connect to the Nantahala and toward Tennessee. Those are the lands set aside: for wildlife coming home, for the hikers and hunters coming to the woods, and for clean water flowing toward the cities below.

SUSPENDED BENEATH ITS EGG MASS, A SPOTTED SALAMANDER GUARDS THE FUTURE.



DERRICK HAMRICK

## AGGRESSIVE CONSERVATION for the NEXT CENTURY

During much of the twentieth century, conservation focused on acquiring land in order to preserve threatened pieces of natural systems—plants and animals, species, and communities. Brown pelicans, bald eagles, Venus’ flytraps, Gray’s lilies, and mountain bog turtles are among the many rare and sensitive species that have benefited from such representative preservation. Saving as many of the pieces as possible should remain a fundamental objective of conservation. Native species are the building blocks of ecological communities, and the diversity of species is the basis of the future evolution of communities and ecosystems as well as of new species. Preserving the greatest array of native plant and animal species will improve the ability of natural systems to respond to change over the next century. Because there is no threshold of nonviability that is scientifically definable in most practical circumstances, few, if any, species should be considered hopeless. As Aldo Leopold advised, “To keep every cog and wheel is the first precaution of intelligent tinkering.”

But representative preservation alone is not enough. Far greater and bolder conservation will be required if the North Carolina landscape in 2100 is to truly meet the needs of its people. Today, conservation professionals from activists to academicians and agency personnel are modifying their work to reflect the maturing objectives of conservation biology. A variety of lessons learned provide the scientific basis for more meaningful and aggressive conservation than has marked past efforts. It is equally important that the general public understands and supports this emerging emphasis on the sustainability, comprehensiveness, and functional integrity of conservation.

The goal of aggressive conservation is to ensure that the state’s native ecosystems are conserved and restored at appropriate scales to optimize ecological function and integrity. This means that in addition to maintaining a diverse array of native plants, animals, and ecological communities, aggressive conservation thoroughly restores and protects the ecological processes that drive and define ecosystems. In addition to the ethical or spiritual arguments for such thorough stewardship, there are simple utilitarian reasons: functional and integrated ecosystems provide invaluable services on which people depend. Aggressive conservation protects not only the habitats of plants and animals but the human habitat as well.

Healthy ecosystems purify air and water, mitigate droughts and floods, regulate climate, generate fertile soils, detoxify and decompose wastes, and cycle and move nutrients. Only through aggressive conservation at landscape and watershed scales will it be possible to maintain the proper function of these vital, natural processes. This means that most, if not all, of the land in North Carolina should be better managed to contribute to ecological objectives, even while serving more consumptive human interests.

HORIZON 2100 holds that North Carolina must greatly accelerate efforts to meet both aspects of the conservation challenge: (1) to preserve most, if not all, of the pieces and (2) to protect the processes that knit together these interdependent pieces, sustaining overall environmental health. Choosing to ignore either aspect of this challenge is a recipe for failure. In addition to

representative preservation, successful conservation must include the prudent management of all activities that distribute, accumulate, and transport materials that can artificially alter natural processes, particularly nutrients, toxicants, metals, sediment, oxygen-demanding substances, and pathogens. Rates of pollution and waste should not exceed the assimilative capacity of the natural environment. Patterns of water flow off the land or into the groundwater, atmospheric deposition of materials, and maintenance of nutrient cycles require careful management.

Many things will change during the next century, but the ecological imperatives that govern natural systems today will govern natural systems in 2100. The ecosystems that maintain human societies must be maintained by human populations. Protecting the function and integrity of ecosystem processes is the best and most cost-effective means of ensuring an environment in which future North Carolinians will be able to flourish.

HORIZON 2100 anticipates a future in which the economies of nature and of humans are united, and humans are an integral part of the natural system. This in no way suggests that all lands should be open to intense human use but emphasizes instead that virtually all of North Carolina, including lands subject to considerable human use, should be managed to support natural function. From water quality to wildlife habitat, most natural system components can benefit from improved stewardship of less than pristine lands.

Therefore, aggressive conservation demands better stewardship of human-dominated landscapes. There is enormous opportunity to reap ecological benefits from private lands, particularly large working landscapes such as agricultural lands and managed forests. Traditional regulatory policies alone will not be enough but can be supplemented by incentive programs to enhance the stewardship of private property.

The places where people live, work, and play—including even the most developed, urbanized acre—can provide some level of ecosystem function: consider a peregrine falcon perched atop a utility pole in downtown Raleigh, hunting pigeons. There is a growing consensus among scientists that with inspired urban and suburban planning, even backyards and the grounds around commercial businesses can provide limited but valuable habitat and a functional connection to natural landscapes.

PEREGRINE FALCON



USFWS

## IN YOUR OWN BACKYARD

Backyard trees thronged with migrating northern orioles and nesting scarlet tanagers. Hawkmoths and butterflies feeding in colorful plots of native shrubs and flowers. Breeding frogs and salamanders migrating to small ponds and seeps. These are not accidental visitors to overlooked lawns but the likely result of carefully considered, intentionally designed backyard landscapes. Softening the interface of urban and wild areas and the impacts of dense human development involves a confluence of landscape design and ecological principles designed to:

- Minimize pesticide and herbicide use
- Curtail stormwater runoff
- Conserve fuel and water
- Maximize oxygen production
- Bolster native wildlife populations
- Discourage non-native, invasive plant species

The edge effects (for example, increased predation and reduced nesting success) of suburban developments have been demonstrated for woodland and forest birds, and researchers recently have learned that grassland bird species frequently avoid suburban edges as well. In fragmented urban landscapes small mammal populations can increase and invasive species find ripe conditions for exploitation. Urbanization occurs too quickly for evolutionary adjustment. Yet there are ways to mitigate negative impacts along the suburban/rural interface and to bolster the ecological function of even small urban natural spaces.

The benefits to human lives and welfare and to ecological systems go far beyond the boundary of the backyard. Yards designed with native plants support ecological connections to greenway riparian zones, which provide physical connections—through tributary and mainstem river networks—to distant natural areas. Running along an urban greenway, city dwellers see, feel, and sense greater connections to wild lands. Fishing in an urban park, city children catch migrating shad, and learn that backyards are a part of a greater ecological mosaic.

Each piece of land—urban park, backyard, greenway—can contribute to ecosystem function and a greater awareness of how people affect that function. But this can happen only through the intentional design of human spaces.

### REFERENCES:

- Paton, P.W.C. The effect of edge on avian nest success: how strong is the evidence? *Conservation Biology* 8:17-26, 1994.
- Blair, R.B. Land use and avian species diversity along an urban gradient. *Ecological Applications* 6:506-519, 1996.
- Bock, Carl E., Jane H. Bock, and Barry C. Bennet. Songbird abundance in grasslands at a suburban interface on the Colorado high plains. *Studies in Avian Biology*, 19:131-136, 1999.
- DeLeo, G.A. and S. Levin. The multifaceted aspects of ecosystem integrity. *Conservation Ecology* vol. 1, no. 1:3, 1997.

LARGE CORE  
NATURE  
PRESERVES  
ASSURE  
WILDERNESS  
AND WILD-  
NESS FOR  
FUTURE GEN-  
ERATIONS.



T. EDWARD NICKENS

## FOUR STRATEGIES ESSENTIAL to AGGRESSIVE CONSERVATION

Protecting natural processes and better integrating human activity with the rest of nature will require bigger and smarter preservation, restoration, and management strategies; four key strategies are described here. With aggressive conservation and significant changes in public policy, North Carolina can attain the healthy, natural environment envisioned in HORIZON 2100. Following discussion of each of the four strategies, HORIZON 2100 offers specific policy recommendations to begin implementation of aggressive conservation.

**ONE STRATEGY 1:** Establish a network of optimally located, sufficiently large, well-connected nature preserves, including both lands and maritime preserves, managed explicitly to maintain ecosystem processes and biodiversity.

Multiple large, core reserves in each of North Carolina's physiographic regions—mountains, Pied-

mont, Coastal Plain, and Tidewater—as well as in selected estuarine and marine areas will allow for the continuation of those landscape- and watershed-scale natural processes that have shaped North Carolina's environment and support human life.

Natural disturbance regimes such as fire and periodic flooding, interactions between predators and prey, migration of organisms, conservation of genetic diversity within and between populations, and the function of ecological communities all depend on large areas of intact landscape, as close to their natural condition as possible. Broader-scale ecosystem processes, such as nutrient cycling and air or water purification, also are dependent on large blocks of natural landscape. In addition, large core areas are the only means by which wildness and wilderness can be preserved for future generations.

Size matters, because the opportunities for positively affecting individual plant and animal species, ecological communities, natural interactions between species, and ecological processes multiply as the area under conser-

vation management expands. The rationale for establishing large core reserves is based on ecological studies of islands, which are isolated from other landmasses much as contemporary natural areas in the human-dominated landscape exist as islands of nature and natural processes. Larger reserves contain more species, are more insulated from extinctions, and contain greater genetic variation than do smaller reserves. Small landscapes are more vulnerable to disruption. Larger reserves allow more flexible responses to changes such as a growing population, global warming, and a rising sea level.

Large core reserves are essential to the long-term health of many of North Carolina's native species. Red wolves and black bears require large territories in which to hunt, forage, and reproduce. Elk, such as those reintroduced into the Great Smoky Mountains National Park, are dependent on large areas of habitat. Mountain lions roam over enormous territories. If they are ever to be reintroduced into North Carolina, large core reserves relatively free from permanent human intrusion will be critical.

Even smaller animals rely on large blocks of natural landscape. Recent studies of songbirds in the Great Smoky Mountains suggest that such core reserves act as biological “sources,” producing a surplus of birds that then repopulate surrounding and distant regions where human development has created population “sinks.” In

BULL ELK



DERRICK HAMRICK

the same way, large core reserves in aquatic settings would function as nursery sites for the high percentage of marine fishes that spend much of their juvenile life stages in North Carolina estuaries. These “recharge zones” would act as population sources for surrounding waters open to sustainable harvest.

In addition, careful conservation must connect these large “islands of preservation” in ways that enhance ecological function. Even the largest possible core reserves in North Carolina are likely too small to ensure the long-term viability of species that range and forage widely. Natural corridors allow animals to travel between seasonal habitats and to explore and repopulate distant regions. Corridors can increase the immigration rates of species and allow genetic interchange between plants

## BIODIVERSITY AND REFUGE AREA

Ecologists have long recognized that larger land areas contain more species. When the number of species within a grouping of organisms—mammals, birds, amphibians, plants, etc.—found in given areas of land is graphed, the result (on a logarithmic graph) is a straight line with a slope characteristic of the group of organisms in question (D.H. Wright 1987). This indicates a strong correlation between biodiversity and refuge area. As natural systems are converted to human use and area of habitat decreases, the number of species decreases as well.

This relationship can be used to predict the number of species of a given group of organisms that will persist in a refuge of a given size. For example, if 200 species of birds breed in a refuge of 32 million acres (approximate size of North Carolina), data suggests that only 100 would survive if the area of refuge were reduced to 10 million acres in a single refuge. In other words, about half of the species would become extinct in this reduced habitat. If the 10 million acre natural area were also fragmented into several smaller refuges, even fewer species would be expected to persist.

Thus, “size matters”: a greater amount of area preserved results in a greater number of species that will persist for the benefit of future generations.

### REFERENCE:

Wright, D.H. 1987. Estimating human effects on global extinction. *International Journal of Biometeorology* 31: 293-299.

and animals so that populations in core areas are not genetically isolated and so vulnerable to extinction. Connectivity allows both animal and plant populations to move in response to environmental change and natural disasters and provides for a greater number of protected habitat types for species that rely on multiple habitats. Ironically, roadways, railroads, and other human “transportation corridors” have significantly contributed to habitat fragmentation and destruction.

Natural lands connectivity is critical because it supports the landscape’s ecological function while allowing for its greater use by a growing human population. Devising and implementing a series of ecologically functioning corridors between core reserves and other blocks of protected landscape would mitigate the fragmentation of landscapes beyond the borders of core reserves. The recent acquisition of lands along Juniper Creek, linking the Green Swamp and Waccamaw River in southeastern North Carolina, is an inspiring example of corridor building. Another example is the 30,000 acres of forestlands recently set aside in Duplin and Pender counties, which can ultimately be restored into effective natural corridors between the sprawling Angola Bay and Holly Shelter Game Lands. Clusters of currently protected areas such as the Alligator River, Lake Mattamuskeet, and Pocosin Lakes National Wildlife Refuges could be used for broad-scale corridor networks. It would be a more daunting, but still achievable, project to establish conservation corridors linking the hardwoods of the northern Piedmont to foothill and mountain preserves.



CANADA  
LILY

JOHN SUTHER

### Recommendations: Better preservation of North Carolina’s natural heritage

■ Acknowledge and address the need to set aside a minimum of approximately 30 percent (10 million acres) of North Carolina’s landscape to be managed for natural system integrity and function as its “highest and best” use. If such purposes were made the priority in management of the three million acres in the state that are currently publicly owned, North Carolina would already be nearly a third of the way towards this objective. Many human activities such as fishing, hunting, camping, and even limited timber harvest on these lands can be allowed as long as they are consistent with this “highest and best” use. In addition to these preserves, much of the remaining 22 million acres of North Carolina should still be working farm and forestlands, which would be managed to complement the function of the core preserves. A network of scientifically designed marine protected areas should also be set aside for preservation.

■ Strengthen North Carolina’s Natural Heritage Program. The state’s biennial protection plan should be expanded to account for habitat condition, landscape context, and natural process protection. Conservation of aquatic communities should be specifically addressed. The plan should guide state conservation strategies and identify the landscapes critical for ecosystem processes, which should be restored and otherwise protected.

■ Increase funding to the four major conservation trust funds (Clean Water Management Trust, Natural Heritage Trust, Parks and Recreation Trust, and Farmland Preservation Trust) providing sufficient resources to support natural area restoration and management.

■ Establish sufficient revenues for management of natural area preserves. Important management strategies such as prescribed fire and hydrologic restoration will require substantial support and policies to limit liability.

■ Streamline and increase funding for the state’s environmental preservation, restoration, and management work.



BOBWHITE QUAIL

NCWRC

### AMBER WAVES of BIG BLUESTEM

WHAT IT COULD BE IN 2100



JOHN SUTHER

The phantoms flower in autumn: The fuzzy gray-blue blossoms of big bluestem nod five feet above the ground. The meadows are awash with Georgia aster and split-beard, its white-tufted flowers like tiny sets of rabbit ears backlit in the sun. Indian, switch, and plume grass ripple in the wind. There is Schweinitz’s sunflower and dropseed, deertongue, and Virginia wild rye, all in a rolling, rumpled quilt of prairie tucked into the big woods of the Piedmont.

Teased back to life, prairies in the year 2100 are once again a vital, vibrant part of the Piedmont landscape. It was this way in 1700 when the colonial explorer John Lawson described a prairie near Salisbury that unfurled for 25 miles. It was

this way in Gaston County in the years after King’s Mountain, when horses were turned loose in the high prairie grass on Saturday and fetched on Monday by the tinkling of their bells. Now 15 prairie sites stipple the state’s midsection, enough to remove Schweinitz’s sunflower from the federal Endangered Species List. Enough to support the clan of elk at Cowan’s Refuge in Mecklenburg County. There are prairies in Union County and Rowan County and Cabarrus County. In Mecklenburg County alone, they cover 1,000 acres, an ever-changing palette of color, from spring green to summer blue to bronze and purple in the fall. These aren’t the sprawling grasslands of olden times. But in 2100 you can lose yourself in a flower-dappled plain where the trees are a distant blur. You no longer have to wonder what a Piedmont prairie was.

“Save all the pieces.” This is what ecologists urge, and this is what they mean: Save the silver plumegrass and the purpletop. And save the natural community they comprise. These are the small cogs and wheels of the North Carolina landscape, and by saving the pieces we save the possibilities. The possibilities of Bachman’s sparrows and vesper sparrows and bobwhite quail calling from the tall sedge. Of elk. Of amber waves of Indian paintbrush and turtlehead. Save the pieces, and we give to those who will come after us the gift of being able to make their own choices, like spending an autumn day in a Piedmont prairie.

## two STRATEGY 2: Reestablish natural landscapes through active restoration and natural regeneration. Repair past ecological degradation so that natural systems can support future ecological and human needs.

From wildflowers to forests, from shrimp to rabbits, from soils to clean water, natural resources are consumed by humans. When human use or harvest of a natural resource exceeds natural rates of regeneration, it can trigger a cascade of negative effects, undermining ecosystem health. History is rife with examples of animal and plant species overharvested to the point of population collapse and even extinction. Native North Carolina wildlife such as Carolina parakeets, wolves, and passenger pigeons were extirpated by overharvesting and outright persecution. White-tailed deer were eradicated from most of North Carolina by 1925; wild turkey numbers bottomed out to a mere 2,000 birds in the state during the 1970s. Many marine fish species, such as



DOUGLAS N. RADER

## OYSTERS: SHELLFISH AS FOOD, FILTERS, AND CRITICAL HABITAT

As filter feeders, each adult oyster pumps approximately 50 gallons of water through its gills per day, removing algae and other particulates as food. When European explorers first sailed into Pamlico Sound, the oyster reefs were so large and numerous that they presented a significant navigational challenge. At their population peak, Pamlico Sound oysters could filter the entire volume of water in the estuary every four to five days [NC DENR, 2001].

Today, North Carolina's oyster population is estimated to be only 1 percent of its historic level, the decline caused by centuries of cumulative abuse from coastal development, worsening water quality, disease, and harvest [Marshall, 1995]. The challenge is no longer one of navigation, but rather restoration: How do we rebuild an oyster population that supported a once-thriving fishery and provided untold thousands of acres of critical habitat to fish such as red drum and sea trout?

One "restoration" technique being considered relies on the introduction of the nonnative Asian oyster. Supporters of this initiative point to the nonnative's resistance to the decimating diseases Dermo and MSX. However, recognizing the potential for unintended consequences and believing that successful restoration could be achieved with native oysters, many authorities question the wisdom of using a nonnative. Will a nonnative provide the same important habitat functions as the native oyster does? Will it build reefs, as our native oyster does? How much will it cost to raise enough nonnatives to replace the current stock of natives and build a viable, marketable fishery?

### REFERENCES:

NC DENR. 2001. North Carolina Oyster Fishery Management Plan. NC Division of Marine Fisheries, Morehead City, NC, 217 p.  
Marshall, M.D. 1995 North Carolina Oyster Restoration and Fishery Management Plan. NC Division of Marine Fisheries and the NC Blue Ribbon Advisory Council on Oysters. Morehead City, NC, 116p.

A SMALL, WET MEADOW ABLOOM WITH INDIAN PAINT-BRUSH AND ATAMASCO LILY RECALLS THE ONCE VAST NORTH CAROLINA PIEDMONT PRAIRIES.



JOHN SUTHER

river herring, striped bass, and Atlantic sturgeon, supported enormous commercial fisheries before the mid-twentieth century, at which time their populations collapsed.

In the past, many plant and animal resources were viewed strictly as commodities, and not appreciated as vital pieces of complex ecosystems. During the timber boom of the early-twentieth century, mountain spruce-fir forest communities nearly vanished, and along with them, a unique community of mosses, spiders, and birds. Oysters offer another example of excessive consumption; so popular as a culinary delicacy, the oyster's importance to estuarine habitat was virtually ignored as they were aggressively overharvested. Oyster reefs are critical habitat for fish and shellfish and they are natural filters, removing pollutants from water. The loss of more than 99 percent of oyster reef habitat in the North Carolina estuaries since 1900 has robbed the region's economy and cultural history.

In addition to depleting plant and animal species, human alteration of landscapes and pollution have undermined natural system processes. For example, more than one-half of the 11 million acres of natural North Carolina wetlands, which are crucial to water purification, have been ditched, drained, and otherwise destroyed. As more land is subjected to intense human use and as the air and water becomes more polluted, the environment becomes less hospitable to the species—including humans—that depend on it. Nonetheless,



DERICK HAMRICK

YELLOWBELLY SLIDER

with careful attention and planning, many natural systems can regain their natural function and health. This lesson must be learned: it is usually far more cost-effective to protect the natural function of the environment than it is to restore it once it has been lost.

To envision a North Carolina restored and naturally functional, from the mountains to the sea, requires an understanding that land use is not fixed. The fact that a certain piece of land is a soybean field, industrial tree farm, or riverside junkyard does not preclude another status for it in the future. Indeed, many of North Carolina's current landscape-scale conservation successes, including the Uwharrie and Pisgah National Forests, Umstead State Park, and much of the Great Smoky Mountains National Park, were not set aside as virgin forests. Instead, many of these natural jewels were

“It is more cost-effective to **protect** the natural environment in the first place than to **restore** it after it has been **lost.**”

acquired as cutover timberlands and eroded farm fields, but today they are recovering, through active management and natural regeneration, to a more natural state.

Restoring degraded landscapes requires long-term commitment. The spectacular vistas of the Blue Ridge escarpment, enjoyed today by millions of travelers along the Blue Ridge Parkway, returned only after a half-century of dedicated public-private partnerships and state and local community support. Similar efforts will be required to identify, preserve, and restore those pieces of the current North Carolina landscape that hold the most potential as the Piedmont prairies, canebrakes, wetlands, forests, and coastal shorelines of the future.

Restoration efforts should focus on replacing lost or diminished natural functions. Sites retaining as much of their natural character as possible are best suited for restoration attempts. These sites have the capacity to regenerate significant biodiversity and valuable ecosystem services. Additionally, some marginally productive farmlands can be more efficiently used for conservation purposes. The management of many industrial pine plantations could be reshaped to incorporate species richness and diversity, watershed protection, and public recreation on a scale that would result in a more balanced landscape.

Aggressive conservation and restoration also call for the thorough rewilding of some areas. A rewilded area is one in which all aspects of the ecosystems—including hydrological processes, fire regimes, and trophic (food web) systems—are as fully rebuilt as possible. Rewilding does not mean simply setting areas aside; it entails extensive, and sometimes expensive, management. Some lands already in public ownership, particularly national and state forests, should be expanded and rewilded, reintroducing predators and

## WHY PREDATORS MATTER

The manner in which ecosystems are regulated and maintain functional balance is complex. The “top down” theory of ecosystem regulation emphasizes the importance of predators, for without them, the populations of prey species can explode, unleashing a cascade of negative ecological consequences. Excessive numbers of herbivores can quickly overexploit and decimate ecosystem integrity. Ample evidence supports the theory of regulation by top-down predation. One recent study, comparing predator-free islands with the nearby mainland where predators remained, found that the densities of prey species were 10 to 100 times greater on the islands (Terborgh, et al 2001). The study also provided evidence of a trophic cascade resulting from the absence of top-down regulation. The study observed that on the herbivore-dominated islands, the densities of seedlings and saplings of canopy trees were severely reduced, adversely affecting the ecosystem.

Populations of white-tailed deer, a common North Carolina species, have exploded in areas where they are free from predators. A number of studies have revealed that large numbers of white-tailed deer hurt native biodiversity. Research in South Carolina has shown that Catesby’s trillium stems were 68 times denser in suitable habitat inside a deer-proof enclosure. Another study suggests that deer densities greater than 25 per square mile are not compatible with oak regeneration. Studies in Pennsylvania have quantified the impact of high densities of deer on songbird populations as follows:

Deer density	Species lost
>20/square mile	shrub-nesting least flycatcher, eastern wood peewee, indigo bunting, yellow-billed cuckoo, cerulean warbler
>38/square mile	eastern phoebe, American robin

Ground nesters such as quail, woodcock, wild turkey, grouse, and ovenbirds are also significantly reduced as the shrub layer thins (De Calesta, 1994).

For comparison, 38 North Carolina counties include deer densities greater than 40 per square mile, while the majority of land area in North Carolina hosts an average of more than 20 deer per square mile (Osborne, 1998).

### REFERENCES

- DeCalesta, D.S.. 1994. Effects of white-tailed deer on songbirds in managed forests in Pennsylvania. *Journal of Wildlife Management* 58: 711-718.
- Osborne, Scott. 1998. “Too Many Deer?” *Wildlife in North Carolina*, September 1998: 16-19.
- Terborgh, John, et al. 2001. Ecological meltdown in predator-free forest fragments. *Science*: vol. 294, no. 5548: 1923-1926.



NCWRC

THE REINTRODUCTION OF THE RED WOLF IN NORTH CAROLINA MARKED THE FIRST TIME THAT A SPECIES EXTIRPATED IN THE WILD WAS RELEASED INTO ITS FORMER RANGE.

natural disturbance processes. Rivers should be rewilded by conserving and restoring riparian buffers and opening up ancient migration paths by removing and bypassing dams. Already steps are in place to restore ancient runs of migratory fish such as striped bass, American shad, and shortnose and Atlantic sturgeon to Coastal Plain rivers. In the last five years, three dams have been removed in North Carolina, opening up more than 1,125 miles of historic spawning habitat to migrating fish.

Rewilding the landscape with natural disturbance regimes is critical. Much of what modern society has been conditioned to consider as “natural disasters” (for example, floods, fires, and diseases) are actually ecological processes that enable natural systems to recharge and replenish themselves. Like fire, flooding is a natural con-

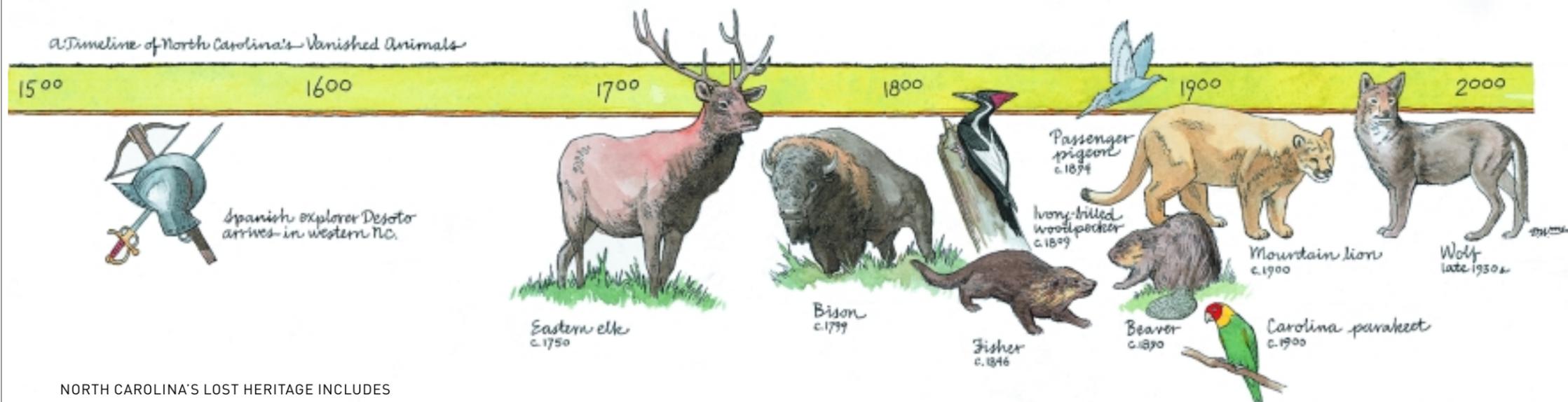
dition and one that humans have altered in ways that have adverse impacts on ecological processes. As late winter and spring rains swell Coastal Plain rivers, rising and receding waters deposit rich sediments on river levees, which helps create vast hardwood bottomland ecosystems. Spawning fish also time their egg-laying to take advantage of river currents that carry the developing larvae to rich estuarine nurseries. Changing spring river-flow patterns for flood control and power generation affects an enormous number of plant and animal species, and entire ecological communities. Human-induced changes in flooding regimes have been linked to declines in cypress regeneration, nesting success of ground-nesting birds such as wild turkeys, and anadromous fish spawning.

Returning carnivores to the top of the food chain in some parts of North Carolina is important. The disappearance of apex predators hastens the unraveling of natural processes. Carnivores are needed to control the prey species with which they coevolved; as predators are removed, prey populations will mushroom to abnormally high densities. Since most prey animals are herbivores, their rise in numbers overwhelms plant communities. In North Carolina, white-tailed deer, raccoons, and

beavers were once controlled by large predators such as wolves and mountain lions. Now, virtually free from predators, the populations of these prey species have exploded, and they are not just nuisances to backyard gardeners, bird-watchers, and forest owners but pose serious threats to biodiversity.

There are now more deer in America than were here when Europeans first colonized the continent, and their exceedingly high numbers are dramatically changing the composition of forests. By overbrowsing native vegetation, deer shape the woods for decades to come and suppress animal and plant species as diverse as yellow-billed cuckoos, flying squirrels, and white oaks. Ground and shrub-nesting birds such as ovenbirds, hooded warblers, and least flycatchers are left with fewer nesting sites, and with only a thin shrub layer left in the woods, snakes, raccoons, and hawks have an easier time finding nests and young birds. Meanwhile in some woodlands, native plants such as trilliums and lilies have been browsed to near oblivion.

North Carolina already has returned some predators to the landscape. Today more than 100 wild red wolves range over a five-county, million-acre wolf reintroduc-



DAVID WILLIAMS

NORTH CAROLINA'S LOST HERITAGE INCLUDES ANIMALS AND PLANTS THAT HAVE VANISHED FROM THE STATE OR GONE EXTINCT.



JOHNNY RANDALL

## NONNATIVE INVADERS

Invasive alien species, both plant and animal, are a challenge to global conservation that threatens North Carolina’s natural areas, economy, and even public health. The population densities of scores of plant and animal species that evolved elsewhere—from lands as close as the tropics to as distant as the West Nile region of Africa—can explode when introduced because they have escaped the factors limiting their populations in the regions where they evolved.

North Carolina faces a choice—a landscape increasingly overrun with invasive species that alter our ecosystems and reduce species diversity or a landscape characterized by diverse, endemic, and natural southeastern communities. To help turn the tide, the North Carolina Botanical Garden is promoting a code of conduct for horticultural institutions to respond to new plant invasions, to find alternative species for those invaders already in horticulture here, and to eradicate invaders from our natural areas.

### Beyond Kudzu: The Least-Wanted List

Chinese chestnut blight	By 1950 eliminated native chestnut trees
Balsam woolly adelgid	Beginning in the 1960s, devastated native stands of Fraser fir
Dogwood anthracnose	Has all but eliminated the state flower in shady mountain woods
Gypsy moth	Decimates native forests
Flathead catfish	Wipes out native catfishes and some sunfish species, including the beloved redbreast sunfish
Hemlock woolly adelgid	Killing mountain hemlocks, key species for trout and songbirds
Chinese privet	Grows dense in Piedmont bottoms, choking out native trees and wildflowers
Asiatic clam	Colonizes streams in enormous numbers, reducing habitat for native mollusks
Japanese stiltgrass	Forms massive single-species colonies in floodplains and moist woods
Autumn olive	Escapes from backyard plantings to crowd out native shrubs in Piedmont uplands
Nutria	Destroys saltmarsh, outcompetes native furbearers
Water hyacinth and salvinia	Floating aquatics clog rivers, alter stream and pond ecosystems
Alligator weed	Worst invasive aquatic plant, smothering rivers and backwaters
Phragmites	Worst invader of North Carolina marshes. This European strain is likely to complicate the natural migration of marshes as sea level rises.
Japanese honeysuckle	Pervasive invader in the Piedmont and richer parts of the Coastal Plain and lower mountains; smothers trees and tree regeneration.
Russian olive	Increasing in Piedmont forests, may soon be worst of invasives.
Feral (once domesticated) pets and livestock	Major threat to native flora and fauna statewide.

tion project area in eastern North Carolina. In the 1990s nearly 300 river otters were reintroduced into 11 western Piedmont and mountain streams. Coastal Plain bear populations have surged. Yet wolves are still absent from the mountains, and there are no wild mountain lions in the state. Restoring suitable habitat for apex predators is an essential component of rewilding North Carolina. Even successful restoration programs will not bring back sufficient numbers of predators to control deer populations; therefore, reducing deer numbers by other means will be a necessary component of rewilding.

Restoring nature entails mostly bringing back what is gone, but it also must include getting rid of what does not belong. North Carolina has been and continues to be invaded by a witch’s brew of exotic plant and animal species. Nonnative plants change natural hydrological and nutrient cycles, disrupt natural disturbance regimes, and short-circuit natural succession. In many cases, native plant species can no longer compete successfully for space and nutrients. Invasive plants can simply take over; kudzu and Japanese honeysuckle now suffocate sprawling acreage across North Carolina and more than 14 million acres in the southeastern United States. Dense mats of shade-tolerant Japanese stiltgrass cloak North Carolina creek banks, floodplains, and swamps. Aquatic weeds such as alligator weed, giant salvinia, and hydrilla choke waterways. Most, if not all invasive plants are here to stay, but efforts to slow their spread and mitigate for negative impacts are critical.

Invasive animals are similarly problematic. Untold millions of Asiatic clams litter freshwater creeks and streams in lieu of native clams and mussels driven off by plunging water quality. Nutria gorge on coastal marshes. The flathead catfish has dramatically altered Coastal Plain rivers, reaching densities as high as 900 per kilometer in some North Carolina stream sections. The venomous lionfish from Australasia, brought into the country as a pet in home aquariums, has recently been found in North Carolina’s marine waters. Nonnative insects ravage forests across the state, and the distribution of exotic diseases (chestnut blight, Dutch elm disease) has had massive impacts, driving native species to extinction and dramatically altering ecosystem function. Today, West Nile virus poses enormous threats to

the bird populations of North America. Providing a future North Carolina environment characterized by intact natural systems requires stringent controls on the movement of nonnative species into and within the state and strong measures to remove current invasive species.

### Recommendations: Better restoration of degraded natural systems

- Reestablish viable examples of all major ecosystems naturally found in North Carolina, including Piedmont prairies, canebrakes, longleaf pine forests, stands of Atlantic white cedar, old-growth hardwood forests, mountain bogs, cypress-tupelo swamps, and nonriverine wet hardwood forests. When disease-resistant stocks are available, reestablish viable populations of important trees such as chestnut and elm.

- Reform transportation policy to protect and, where necessary, allow restoration of environmental function and quality. Require full mitigation for all adverse impacts from highway projects to ensure no net loss of ecosystem function and quality. While ensuring safety by maintaining and improving existing roadways, reduce emphasis on new roads and encourage alternative, less environmentally damaging modes of transportation.

- Coordinate restoration projects more efficiently with natural area preservation to contribute to the overall protection and restoration of natural system processes.

- Restore significant areas of native oyster reefs in North Carolina estuaries, and expand other areas of significant aquatic habitats. Strategies must include restoring the natural hydrology in, and eliminating pollution to, North Carolina streams and rivers.

- Support reintroduction of top predators such as eastern cougar and wolf.

- Control, and where feasible and advantageous, eliminate populations of invasive species while implementing programs to restrict the entry of new, potentially damaging species.



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AUTUMN ALONG THE MIDDLE PRONG, AN EXQUISITE EXAMPLE OF THE NATURAL RESILIENCE OF FORESTS.

**three** **STRATEGY 3: Restore and maintain the quality of air, water, and soil. Maintain appropriate mass balances and cycles of nutrients and carbon, and the environment's ability to detoxify wastes.**

Although it is possible to protect certain aspects of natural heritage in isolated preserves, the protection of water, air, soil, and nutrient cycles must extend across the landscape and will require strategically and geographically comprehensive conservation. Nearly every acre in the state, whether private or public, should be managed so as to maintain the balance of these natural system elements. Unfortunately, the state regulatory programs addressing this need are weak, uncoordinated, frequently unenforced, and woefully underfunded.

Because it is neither practical nor desirable to attempt to protect the state's water, air, and soil through regulation alone, creative incentive programs are a promising way to ensure a successful marriage of public benefits and private interests. However, these currently popular programs must be understood as complements to, rather than as replacements for, baseline regulation and rigorous enforcement. Ecological systems are resilient, but they have only a finite capacity to detoxify the varied and considerable wastes that can accumulate, especially as by-products of human activity. Even the discharge of wastes into the air must be controlled to make sure that it does not defile that seemingly inexhaustible natural resource.

North Carolina's streams, rivers, and lakes are among its most threatened natural communities. The



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pollution that threatens aquatic systems comes not only from factories and sewage treatment plants but also from virtually every land-disturbing activity in the state, including crop and animal agriculture, development, and even individual homeowners' use of pesticides and fertilizers. This diffuse runoff, called nonpoint source pollution, is the leading cause of the state's water quality problems. As farms and forests are put to more intensive use, the land loses its ability to absorb and filter runoff. Wetlands, a critical filter protecting aquatic ecosystems, continue to be destroyed across the state. North Carolina's growing population and urbanizing landscape will only make these problems worse.

Lands immediately adjacent to streams, creeks, and other surface waters are especially important to the protection of water quality. Trees, shrubs, and grass along waterways are the ideal way to slow runoff and filter contaminants. In addition to protecting water quality, carefully managed streamside lands provide habitat for a variety of plants, animals, and natural communities both in the water and on the land, and they reduce downstream flooding, stream-bank collapse, and erosion. Protecting riparian buffers along Tar Heel streams and rivers will soften the intersection between human-dominated landscapes and natural systems and processes. In addition to protecting buffers adjacent to streams and rivers across the state, limits should be imposed on the amount of land in any given watershed that can be paved over or built upon (that is, limit the percentage of a watershed in impervious cover). Only

HEALTHY PREDATOR AND PREY RELATIONSHIPS—SUCH AS THIS BARN OWL AND ITS FURRY DINNER—ARE A HALLMARK OF HEALTHY ECOSYSTEMS.



DERRICK HAMRICK

COASTAL SALT MARSH IS ONE OF THE WORLD'S MOST PRODUCTIVE NATURAL COMMUNITIES.

with such protections can the landscape filter out the pollution before it reaches waterways. Although better laws will help, the immediate need is greater financial and political commitment to enforcing the existing rules for stormwater management. Furthermore, North Carolina must do a better job of avoiding and minimizing wetland disturbance. When disturbances do occur, restoration measures should already be in place to return the same full functional values as those that have been lost.

Clean air is another critical component of functional ecosystems. The atmosphere conveys pollutants from both near and far, converging on North Carolina's mountain forests, undermining the natural balance of aquatic ecosystems, and threatening human health in our cities. The North Carolina General Assembly recently took a major stride toward protecting the state's air by passing

the Clean Smokestacks Act to reduce key pollutants from power plants. In addition, it is paramount that North Carolina address emissions from tailpipes, manufacturing-facility smokestacks, and agricultural sources such as livestock operations, as well as pollution sources from upwind states. North Carolina must also draw up and implement a plan to reduce greenhouse gas emissions from all sources and to increase the sequestration of carbon on agricultural and forestlands. (Carbon is stored in soil and vegetation, and with careful management of farms and forests, the amount of carbon released to the atmosphere can be significantly reduced).

Toxic materials and poor stewardship also threaten the productivity of North Carolina soils. Problems with accumulated toxicants exist in urban areas and rural areas alike and have recently been documented in North

### MARSHES that MARCHED

WHAT IT COULD BE IN 2100

In 2003, the sea was rising, and rising ever more quickly as global warming accelerated. The effect: North Carolina's estuarine shoreline was eroding at an average of 3.1 feet per year in the Albemarle, Pamlico, Neuse, and Core-Bogue coastal systems. In the northeast region alone, more than one-and-a-half square miles of land were being lost to erosion on average each year since 1975.

Saltwater intrusion was decimating marshes. Along U.S. 64 and U.S. 264 in Hyde and Tyrell counties peat soils had literally liquefied into black, pasty sludge as seawater invaded freshwater marshes. Activated by salt-laden water, bacteria digested the rich peat soils and released sulfides that killed many marsh plants. From the water, bulkheaded developments stood like buttressed fortresses. The future of North Carolina's soundside beaches seemed destined to be a jumble of failing bulkheads and ugly riprap.

Then the state of North Carolina began to take seriously the protection of tidal ecosystems. Estuarine beaches and mudflats, peatlands and pocosins, tupelo and cypress swamps, and salt and freshwater marshes would have disappeared had it not been for careful conservation and creative management that enabled freshwater ecosystems to retreat inland and upland, while new brackish and saline systems became established in their former places.

Over the decades, North Carolina ensured that the erosion of marshes and wetlands was an orderly retreat, not a complete loss of the front lines. Coastal managers understood that, if allowed, fringe marshes would migrate upland as sea level rose. The state developed land management strategies that aided the migration and resilience of ecosystems, and stabilized the littoral substrate. Well-planned migration corridors allowed saltmarsh cordgrass, black needlerush, salt grass, and cattails to move with a rising salt wedge into up-tide uplands.

The state established strong policies against armored shorelines, disallowing bulkheading and riprap that would have otherwise doomed future estuarine marshes and estuarine productivity. In the same manner that North Carolina had been the national leader in its approach to beachfront management, it proactively adopted policies strictly limiting bulkhead and riprap structures on the estuarine shoreline.

The result? Estuarine shorelines in the year 2100 that are still lined with functional wetlands. Healthy populations of fish and shellfish that spend their natal years in the marsh zone. Higher water quality thanks to marsh root systems that bind the soil.

## HUMAN ACTIVITIES THAT CAN TRIGGER NITROGEN IMBALANCE

During the twentieth century, major changes in natural nitrogen cycles have resulted from human activities, including:

- Energy production that relies almost exclusively upon combustion of fossil fuels, generating significant nitrogen emissions;
- Mass production and use of nitrogen-based fertilizers; and,
- Agricultural practices that increase nitrogen fixation.

Impacts resulting from alterations to the nitrogen cycle include:

- Algal blooms, causing massive fish kills in NC estuaries;
- Reduced terrestrial biodiversity;
- Changes in the composition of aquatic food webs;
- Acidification of soil and freshwater ecosystems;
- High nitrogen in groundwaters, threatening human health;
- Increased air pollution and associated effects on human health.
- Harmful shifts in ground-level and stratospheric ozone; and,
- Global climate changes and sea level rise.

### REFERENCES

Vitousek et al., 1997; Galloway and Cowling, 2002

Carolina estuaries. Superfund sites, solid-waste landfills, leaks from underground storage tanks, and concentrations of mercury in wetland soils all reflect our industrial heritage. Soil lost to agricultural and building practices, past and present, chokes rivers and degrades farm and forest productivity. Even the drainage systems installed in the coastal zone to move water off the land and put wet flatlands into agricultural production continue to stimulate oxidization of the organic matter in soils and to induce soil subsidence and production losses. The soil and water conservation movement was critical to the awakening of the environmental conscience in the mid-twentieth century; returning to these roots is another fundamental element of aggressive conservation.

The healthy function of natural systems also depends on the natural balance of basic nutrients, including nitrogen and phosphorus. Scientists now realize that the alteration of basic biogeochemical cycles constitutes a major threat to natural ecosystems. Large amounts of fertilizers—especially nitrogen and phosphorus from runoff and airborne sources—seriously impair most of the major coastal waterways, inducing serious symptoms of water pollution: algal blooms, deoxygenation of coastal waters (so-called dead water), fish kills, and crab and fish diseases.

In addition to water quality, concerns about water quantity are arising from a history of cavalier management of surface and ground water resources. Given its many rivers, estuaries, and aquifers, North Carolina has always seemed water rich, at least until the recent years of drought. As the earth warms over the next century, the amount of precipitation to recharge these ebbing

water supplies is expected to decline. With a growing population demanding more clean water than ever, North Carolinians must become more efficient stewards of the water that falls on the state in the form of rain and snow. As it flows across the land, the water is withdrawn from lakes, rivers, and underground aquifers for uses as varied as manufacturing paper and cleaning hog pens. The “used” water is then discharged back into the same rivers and lakes, which flow down to our estuaries and coastlines. The water that comes out of a tap in some North Carolina communities often has already been used several times for industrial, agricultural, or domestic purposes. There is the fundamental issue of maintaining adequate supplies of clean water to support human uses. Several aquifers in eastern North Carolina are already being depleted by overuse, and recycling “used” water can be very expensive. Not simply for drinking, clean water is essential to a healthy economy.



DOUGLAS N. RADER

PITCHER PLANT

## Recommendations: Better management of air, water, soil, and elemental cycles

- Meet and maintain water quality standards in all surface waters of the state, and restore and maintain the high levels of water quality needed to support populations of pollution-intolerant organisms.
- Establish regulatory, educational, and incentive-based programs to restore and protect riparian buffers and floodplains on all the state’s perennial and intermittent streams, rivers, lakes, and estuaries.
- Expand the acreage and functionality of all classes of wetlands in all portions of the state while protecting existing wetlands to the maximum extent possible.
- Create a sustainable long-term water supply plan for North Carolina that ensures the safety of all drinking water supplies.
- Deny state permits for any land-conversion activity unless net positive conservation benefits can be demonstrated to offset the negative effects of the proposed activity.
- Seek an expanded regulatory system that ensures the complete baseline protection of natural systems.
- Develop tax breaks and other incentives to encourage private citizens to go beyond regulatory requirements in protecting and restoring environmental function and quality.
- Implement programs to meet ecologically based flow regimes for all river systems across the state.
- Implement programs to ensure that all North Carolinians breathe air that meets health-based standards and that sensitive ecosystems are protected from air pollution.

## four STRATEGY 4: Ensure resilience to accommodate a steadily increasing population and the effects of global climate change.

HORIZON 2100 acknowledges that North Carolina will be a very different place in 2100. The first inescapable reality is the state’s steadily increasing population. Sheer numbers and relentless consumption are putting unprecedented pressure on natural systems. The state’s population of eight million will most likely be double or greater by 2100, but the condition of the future environment will be less a function of the specific number of people and more a function of how those people occupy and use the landscape. The infrastructure to support that growing population may further fragment and disrupt natural systems, but aggressive conservation can enable North Carolina to more effectively weather these changes.

Admittedly, a North Carolina that is home for 16-20 million people in 2100 will have extensive areas of human-dominated landscapes. Nonetheless, with careful management and constraint of the footprint of human activity, nature will persist, ecological processes will continue to provide essential goods and services, and the human inhabitants will thrive. In both rural and urban areas, land use planning and growth management at all levels of government must be greatly improved. Implicit in this view is the need to limit human disruption of natural system integrity and function. Whether considering a single tract or the patterns of human development across the state, development and utilization of natural resources must be efficient, sustainable, and equitable. Clustering human activity, rather than allowing it to sprawl across the landscape, will support conservation needs, reduce the costs and emissions of transportation of people or materials, and will foster a greater sense of community.

Making conservation even more challenging is the second inevitable reality of a changing climate. Most scientists agree that global warming over the next century will reshape North Carolina’s environment and ecological communities. In 2100 the state’s average temperature is likely to be warmer by three to five degrees Fahrenheit. Some scientific models predict that rainfall will be less overall but that large storms and hurricanes will be more severe. Sea level may rise by as much as three feet, and



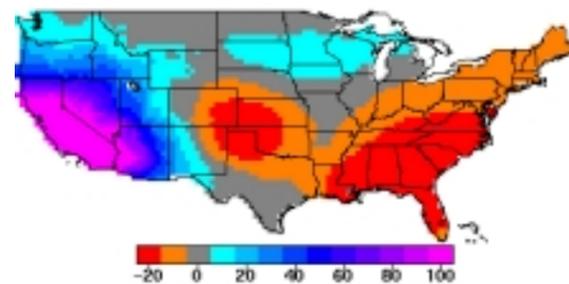
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## MODELING CLIMATE CHANGE

Nearly a dozen models have been developed to predict future changes in the climate resulting from the accumulation of carbon dioxide and other “greenhouse” gases in the earth’s atmosphere. Nearly all of these models show that the earth’s temperature will rise between 1.8 F and 9 F by the end of the century. Predicted increases in the Southeast are more modest, but nonetheless, show an average rise of 1.8 F by 2030 and 4.1 F by 2090.

The models are less consistent in their predictions of changes in rainfall. The Hadley CM2 model shows little change in rainfall by 2030 and an increase, mostly in summer precipitation, of 20 percent by 2095, whereas the Canadian climate model shows a decrease in rainfall of up to 20 percent throughout the southeastern United States and the Great Plains by the middle of the century (Figure 1).

**Figure 1:** Plot of Precipitation Changes for the southeastern United States from the Canadian Model



While none of these predictions can be regarded as definitive, the potential for large changes in rainfall, or in temperature, would have dramatic impacts on the distribution of plants, animals, and infectious diseases throughout the southeast United States.

### REFERENCE:

Southeast Regional Assessment Team, *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change—Southeast*. U.S. Global Change Research Program, Washington, D.C., November 2002

North Carolina’s barrier islands will be significantly breached in the next 100 years. Saltmarshes along estuarine shorelines will either migrate up coastal rivers or be lost. While the most obvious impacts of global climate change will be felt along the coast, no part of North Carolina will be immune. In the Piedmont, hotter, drier conditions could reduce wetland acreage and alter pine and oak composition. Ecological communities now found at the higher elevations of our Appalachian mountains are likely to be displaced. Mountain bogs and glades, each of which are home to many threatened species, could disappear from North Carolina.

These climatic changes will undermine the ability of natural systems to provide the basic ecological goods that people need. Water supplies will be affected, and managing the balance of important natural cycles, like carbon and nitrogen, will be more challenging than ever. Global warming is expected to increase ground-level ozone and the number of unhealthy air days and to reduce crop yields. Perhaps the most frightening aspect of global warming is the increased potential for the spread of bacteria and diseases (examples include the recent outbreaks of malaria, dengue fever, and West Nile virus). Public health may be the single most important rationale for North Carolina to expand its conservation agenda today.

Just as economic models and strategies are being revised by the globalization of the economy, so too must the basic perspective of conservation in North Carolina be revised to acknowledge both the opportunities and the perils of differing strategies. The contention is not that wise conservation alone will control global warming but that North Carolinians, like all responsible citizens of the world, must do their part to reduce and sequester the greenhouse gases that exacerbate global warming. Furthermore, protecting the elasticity of North Carolina’s natural environment could also mitigate the negative impacts felt here.

## Recommendations: Better resilience to anticipated change

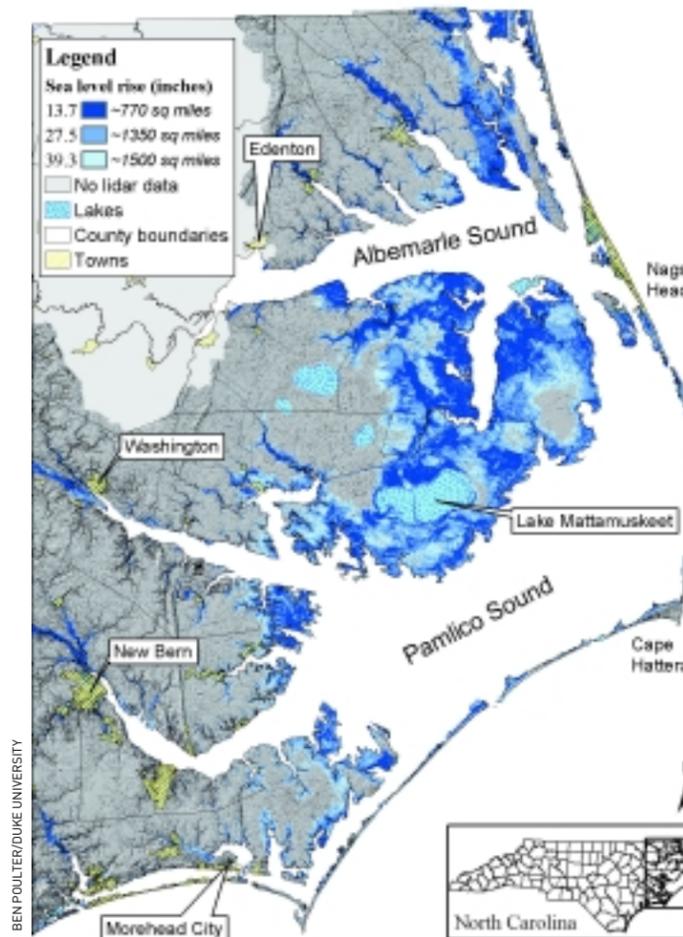
- Require local governments to develop, adopt, and implement comprehensive plans that address land use regulation, growth management, floodplain management, water quality, air quality, transportation, parks and greenways, housing, and capital facilities in order to receive state and federal funds and delegations of authority.

- Ensure that multiple modes of transportation, including light rail, clean-fueled mass transit, and bike and pedestrian paths, receive equal attention as highway projects.

- Establish policies prohibiting use of bulkheads, rip-rap, or other hard shoreline armor on estuarine waters, and otherwise enable the migration of natural systems in response to the rising sea level.

- Establish a greenhouse gas emission reduction strategy so that North Carolina can reduce its emissions to 1990 levels, including a greenhouse gas registry to track emissions, sector-specific emissions caps that harness market forces, and credit considerations for companies that make early reductions.

- Study opportunities for carbon sequestration in agriculture, forestry, and other North Carolina industries to facilitate participation in national or international carbon trading programs as they are developed.



LARGE PORTIONS OF THE OUTER BANKS AND COASTAL PLAIN WILL BE DROWNED BY THE COMBINED EFFECTS OF RISING SEAS AND LAND SUBSIDENCE. THE MAP DEPICTS 3 SCENARIOS OF INUNDATION BASED ON PREDICTIONS OF SEA LEVEL RISE FORECAST BY THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE.

These strategies and recommendations suggest how to better conserve the state’s natural systems. But aggressive conservation will never be more than wishful thinking unless the people of North Carolina understand it, want it, and choose to pursue it. Environmental education is essential. We believe that, when enlightened and inspired, North Carolinians will embrace the necessary actions, both regulatory and incentive-based, to leave a fitting natural legacy. HORIZON 2100 sets the bar and begins the long-term process of education by revealing what is possible; but comprehensive, state-wide education programs at all levels and in a wide variety of forums are needed. Every resident of or visitor to North Carolina should understand the opportunities and challenges of aggressive conservation, and how their choices today will dictate the future.



WOOD DUCK

## PAYING THE COSTS of AGGRESSIVE CONSERVATION

To be sure, aggressive conservation will demand a substantial increase in the pace, scale, and therefore, the costs of conservation. HORIZON 2100 does not offer a restructuring of North Carolina's entire budget, but it does recommend the consideration of green fees and taxes as possible near-term sources of revenue for enhanced conservation.

In addition to raising needed revenue, fees and taxes on services that have negative environmental impacts encourage the reduction of pollution and waste. Examples include severance taxes on the use of nonrenewable resources or sales and use taxes on inefficient vehicles, pollution discharges, construction projects, and solid-waste disposal. Carefully structured taxes and fees can motivate development that complements, rather than conflicts with, conservation objectives. Such fees equitably shift the costs of maintaining the environment from taxpayers to polluters and resource users. Revenues raised by green taxes and fees could and should be directed to conservation and environmental regulatory programs.

Ultimately, however, paying for aggressive conservation will require more than a few green taxes; it will require that North Carolinians alter their fundamental perspectives of what constitutes prosperity, progress, and economic health. In effect, aggressive conservation is an appeal for a new economic model based on environmental stewardship. Economic development has been, and continues to be, the single most important factor driving human use of the land. Therefore, reorienting North Carolina's approach to economic development to focus on long-term equity, efficiency, and sustainability is essential. Such a monumental shift in cultural conscience will evolve gradually, but abandoning policies of uncontrolled growth and development, in which sacrifices to the environment are justified by short-term economic gains, will immediately point the state in the right direction.

Strategies that link conservation objectives and the economic needs of rural North Carolina hold particular promise. Experts in rural economic development have found that what were once simple prescriptions for rural prosperity will not work in the future. Building a new

road or sacrificing local natural resources to lure a new industry is not the solution it once seemed to be. Instead, rural planning initiatives today recommend transforming older communities into mixed-use downtowns, refocusing transportation policies toward public transit and alternative transportation in lieu of more roads, protecting the environment, and managing growth better. All these recommendations, ostensibly to aid rural economies, would also contribute to more efficient conservation of North Carolina's natural capital. Another promising trend is the expansion of federal and state incentive programs that complement basic environmental regulation, alleviating much of the economic pressure on rural landowners and enabling them to preserve the natural function of their lands.

Finally, it should be noted that tourism has become one of the most important revenue producers in North Carolina's economy. With 43 million visitors in 2002, North Carolina ranked sixth among the nation's most visited states. Undoubtedly, the vitality of North Carolina's natural systems is one of the reasons that so many

There is a growing recognition around the world that long-term goals of economic efficiency, fairness, and sustainability can be achieved only by a thorough restructuring of the institutions of both commerce and conservation (that is, aggressive conservation). From relatively rich industrialized nations such as Sweden to impoverished Third World countries such as the Dominican Republic, many countries have begun aggressive conservation initiatives. Certainly North Carolina, a prosperous state in the world's most powerful nation, can and should do more.



DAVID MCNAUGHT

## INCENTIVES TO ACHIEVE PUBLIC BENEFITS ON PRIVATE LANDS

Approximately 85 to 90 percent of the land in North Carolina is in private, not public, hands. Everyone who owns private property is a land manager, and how they manage their property can have an impact on public resources, such as water and wildlife. Success in achieving many environmental goals depends on the actions of individual private landowners. Nearly 90 percent of precipitation in North Carolina falls on private land before reaching streams, rivers, and reservoirs, making private lands critical to clean drinking water.

The importance of private land to conservation is not just a function of its relative abundance, its productive soils, or its access to water. It is also important to sustaining the nation's wildlife resources. Hunters and state game agencies have long recognized the importance of private land for waterfowl, deer, and other game animals. There is also a growing appreciation that privately owned land provides essential habitat for many endangered or at-risk species.

What is the best way to ensure that private land management results in public benefits? Environmental protection has traditionally relied on regulation. But the last 30 years have demonstrated that although regulating the use of private lands may be necessary, it is not sufficient to achieve environmental objectives. Indeed, restoring native ecosystems, protecting habitat, or reducing soil erosion requires the active and willing participation of landowners. To succeed, we must create economic incentives that underwrite the costs of stewardship.

Given the right incentives, private landowners will play a pivotal role in achieving many of the nation's conservation goals. The national office of Environmental Defense is establishing the Center for Conservation Incentives to target existing incentives and to create new ones that will benefit both landowners and the environment. The Center will work with others to develop model programs in North Carolina and around the country. Recovering rare species, restoring degraded habitats, and improving the quality of water in our rivers and streams are just a few of the goals that are clearly within reach if the nation's private landowners are fully engaged.

people want to live or visit here. Therefore, aside from their meeting basic human needs and providing beauty, tranquillity, and inspiration to lift the human spirit, the vital and abundant natural systems are among North Carolina's most important economic assets.

The bottom line is that environmental degradation and pollution are contrary to the long-term interests of

business, commerce, and industry. Aggressive conservation is not a luxury but a necessity, and investments in environmental protection and natural capital make good, long-term business sense. When that fundamental premise is truly institutionalized into economic development policy, North Carolina will find that it has sufficient funds to pay for aggressive conservation.

### NORTH CAROLINA'S CENTRAL PARK

It is a symbiotic relationship: The eight million people who live at the doorstep of the Uwharrie wilds in 2100 could not imagine life without the big woods.

Uwharrie Central Park is the recreational hub for the Piedmont Crescent communities of Charlotte and the Triad. From the city limits of High Point and Winston-Salem, residents can hike, bike, or paddle via the Yadkin River and Uwharrie River Streamways to the Birkhead Mountain Wilderness and beyond, to Morrow Mountain State Park and south to the string of Sandhills Wildlife Refuges buffering the mighty Pee Dee River. Tens of thousands flock each weekend to the clean streams, flowing through a wooded landscape trellised with creeks managed as refugia for freshwater mussels, minnows, and darters. The forests, community-based gardens, organic and specialty farms, and managed timberlands create a mosaic of public and private parklands, serving the whole community.

Nor would the expansive Uwharrie Central Park exist without the people. They are its constituents. They manage the control burns that maintain the oak savannas on the edge of the ridge country, where the Sandhills nudge up to the ancient mountains. They work the farms and the long-rotation woodlots. Locals guide the fishermen to the new miles of smallmouth bass streams that flow cool and clear under the hardwoods. Ecotourist entrepreneurs accompany groups of cyclists, hikers, and kayakers exploring the scenic lanes and waterways.

In 2100 the Uwharrie Central Park is a model for the integration of human communities and the natural world, a place where the natural world could not exist but for the sustaining hand of humans. And humans would not have it any other way.

It could have been a different story. The old, fragmented Uwharrie National Forest, 50,000 acres of widely scattered woodlots, could have been gradually cut down and sold for second-home development and pine plantations. Privately owned woodlands nearby would likely have met the same fate. When the new interstate highway was built on top of the old U.S. 220 corridor, cul-de-sacs and shopping centers could have been planted. A new web of Charlotte bedroom communities could have strung eastward from the 12-lane 485 bypass. Badin Lake and Lake Tillery could have been befouled with wastewater. Half the farmers between Concord and the Montgomery County could have thrown in the towel, selling out family lands as urban sprawl ate away at the region's rural fabric.

Instead, in 2100 one-third of the state's residents live within 30 miles of a wilderness area. Schoolchildren on field trips to old-growth Piedmont oak groves are back in school before the lunch bell. Family farmers retain their farms through environmentally sustainable production. Their sons and daughters, equipped with the best horticultural training from local community colleges, sell fresh and healthy food to an appreciative community. And no one—the Kentucky warblers, the deer, the pinewoods darter, or the people—could imagine it any other way.

WHAT IT COULD BE IN 2100



N.C. DIV. OF TOURISM, FILM AND SPORTS DEVELOPMENT



BIL LEEA

AN UNNAMED WATERFALL TUMBLES THROUGH ROCK, ULTIMATELY SEEKING THE SEA.

## CHOICES

From conservation-minded entrepreneurs to an enlightened citizenry, from private landowners to environmental advocates, from local governments to state and federal agencies—the many diverse entities engaged in environmental conservation should be united and directed towards a common, compelling vision of the best North Carolina that is scientifically possible. HORIZON 2100 provides such a vision.

It has been more than 300 years since John Lawson described the vast and vital environment that European explorers named North Carolina. Today, much less of the natural landscape remains, many natural resources have been diminished, and the numbers and consumptive desires of the human population continue to expand. In another 100 years the condition of the state's environment could be dramatically worse than it is today. Or it could be as good as or better than it is today.

It is impossible to predict with absolute certainty the specific nature of the future. But this much is likely:

In 2100 North Carolina's population will have increased substantially, and probably will have doubled from current figures to 16 million people or more.

The Charlotte-Triad-Triangle region will have coalesced into one large, largely unbroken megalopolis, and the North Carolina coastal region will host a population density similar to the New Jersey shore of 2003.

Global climate change will have altered North Carolina's natural environment. Some barrier islands will have drowned and many mountain bogs will have gone dry. The climate of the state, and perhaps the vegetative and animal communities, will have begun to resemble those found in more southerly latitudes today.

The crown jewels of North Carolina—the Great Smokies, the Pisgah and Nantahala and Uwharrie national forests, the undeveloped shores of Cape Hatteras and Cape Lookout, the pinewoods of the Sandhills—will be the crown jewels of tomorrow. And they will be cherished still.

This is what can be predicted about the North Carolina that our grandchildren will inherit.

The rest is up to us. With aggressive conservation, North Carolina can do far more to affect how future generations enjoy open space, wild lands, and wildlife. Wise stewardship today can leave a legacy enhancing every aspect of life—from public health and safety to economic prosperity—in the North Carolina of 2100.



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*“Nature, to be commanded,  
must be obeyed.”*

Francis Bacon, 1620

## APPENDIX: THE SCIENCE BEHIND THE SOLUTIONS

HORIZON 2100 flows from a clear understanding of the condition of North Carolina’s natural environment. The purpose of this appendix is to link HORIZON 2100 to the wealth of existing research and information upon which it has been built. The following table is designed to assist those readers who may seek further elaboration on the status of any of the many attributes (goods, services, and benefits) provided by the state’s natural systems.

In many cases readers may desire to learn more about the status of a particular wildlife species, habitat type, or other environmental resource. The appendix table is designed to offer both immediate insight and to guide the reader to more complete information. For each of the attributes, be it an animal population, a natural community type, or an ecosystem benefit, the table provides (1) a summary assessment of the status of the attribute, (2) the major threats to the attribute, and (3) the most meaningful and useful documents from which these status and threats were derived.

For example, a reader may wish to know more about native trout. In the table, the reader will learn that the overall status of native trout is severely impaired due to altered habitat and instream flows, declining water quality and territorial invasions by exotic species. The reader would also note that more complete information on North Carolina’s native trout is detailed in Borawa et al. (1998), a publication of the N.C. Wildlife Resources Commission identified in the “Reference” section of the report.

In order to produce a table that is at once comprehensive and manageable, general categories of the status and threats have been established. The status of a given amenity (e.g. species, community, process), based on best professional judgment of the weight of evidence, is ranked in one of five categories:

**Abundant**...the amenity is relatively widespread, and in general is sufficiently represented or provided for in the current North Carolina environment.

**Threatened**...the amenity is relatively widespread, sufficiently represented or provided for, but near-term threats are cause for concern.

**Impaired**...the amenity is significantly reduced in number, distribution, or quality in the current North Carolina environment.

**Severely impaired**...the amenity is only a vestige of its former abundance or quality, and is threatened with further degradation.

**Unknown**...inadequate information exists even to

make an informed guess about the overall condition of that amenity.

A detailed discussion of the threats to North Carolina’s environment is beyond the scope of this report. Existing scientific information on major threats has been summarized, recognizing that the result is simplified relative to the real world. Note that threats listed are principally current threats, although factors that caused important historic losses are also included. The following categories of threats are used:

**Exploitation or consumption** ...direct use of that commodity.

**Habitat alteration**... diminution in habitat value caused by fragmentation, degradation, disintegration or other loss.

**Invasive or exotic species**...direct or indirect damage induced by highly invasive species or by purposeful introduction of competitors or predators.

**Land management**...damage induced by decisions made by human landowners, including agriculture, forestry and development for residential or recreational uses. If only one or two of these three types of activities are dominant, then they are listed separately.

**Water quality**...damage caused by degradation of the quality of the waters in which organisms live, caused in turn by some combination of nonpoint source pollution, waste discharges and airborne pollution delivery. If one or more of these pathways is most important, it is listed separately.

**Air quality**...damage caused by alterations in air quality, either local or regional.

**Global climate change**...damage induced principally by very large-scale alterations in global climatic patterns.

In some cases, more specific threats are recognized, including rising sea level, alteration of the fire regime, beach and dune engineering, feral and wild-roaming pets, accidental kills and “bycatch” in fisheries, and others. Where multiple factors are listed, they are listed in approximate order of their significance.

Citations given present the most important summary documents available pertinent to the status and threats to each amenity. Collectively, these documents describe the status and threats of North Carolina’s natural resources and systems.

The methods used to apply these documents to each amenity presented are presented online at [www.environmentaldefense.org](http://www.environmentaldefense.org). More detailed technical citations are also available at that website.

ATTRIBUTE	STATUS	THREAT/CHALLENGE	MAJOR DOCUMENTS
I. Aquatic Ecosystems			
A. Freshwater Communities and Organisms			
1. Phytoplankton communities in lakes and streams	impaired	water quality	Fensin and Borgh, 2000; NCDENR Basinwide Plans
2. Macrophytes in lakes and streams	unknown/impaired	habitat and flow alteration	Amoroso, 1997
3. Invertebrate communities in lakes and streams	severely impaired	water quality, habitat and flow alteration	LeGrand et al., 2001; NC Div. Water Quality, 1991; NCDENR Basinwide Plans
4. Crayfishes	impaired	water quality, habitat and flow alteration	Clamp, 1999; Taylor et al., 1996; LeGrand et al., 2001; NC WRC nda; Adams, 1992
5. Freshwater mussels and snails	severely impaired	water quality, habitat and flow alteration	Adams, 1990; Williams et al., 1992; LeGrand et al., 2001; NC WRC ndb
6. Native fishes of lakes and streams	impaired/threatened	water quality, exotic introduction, habitat and flow alteration	Braswell, 1991; Menahenick and Braswell, 1997; LeGrand et al., 2001; Warren et al., 2000
a. Native trout	severely impaired	water quality, exotic introduction, habitat and flow alteration	Borawa et al., 1997
7. Lake fishes	inadequately known; mostly abundant	water quality	
8. Amphibians			
a. Vernal pool breeders	severely impaired	habitat alteration	Braswell, 1999; LeGrand et al., 2001
b. Amphibians of lakes and streams	threatened	water quality, habitat alteration	Braswell, 1999; LeGrand et al., 2001
c. Amphibians of rivers (e.g. Neuse waterdog)	impaired/threatened	water quality, habitat alteration	Braswell, 1999; LeGrand et al., 2001
9. Freshwater reptiles	threatened	water quality, habitat alteration	Braswell, 1997, 1999; LeGrand et al., 2001; Herman and Tryon, 1997
B. Estuarine Communities and Organisms			
1. Phytoplankton communities in estuaries	severely impaired	water quality	NCDENR, 2002 (draft); Fensin and Borgh, 2000
2. Macrophytes in estuaries (including submersed aquatic vegetation)	impaired	water quality	SAFMC, 1998a
3. Invertebrate communities in estuaries	impaired	water quality, exploitation	SAFMC, 1998a; Eaton, 2001
4. Crustaceans that use estuarine nurseries (crabs and shrimps)	threatened	water quality, habitat alteration, exploitation	NCMFC, 1999; SAFMC, 1998b
5. Shellfish in estuaries			
a. Oyster beds	severely impaired	water quality, exploitation, exotic introductions	NCDMF, 2001a; Marshall, 1995; SAFMC, 1998a; Bahr and Lanier, 1981; NC DEH, nd
b. Hard clam beds	threatened	water quality, exploitation	NCDMF, 2001b; SAFMC, 1998a
6. Estuarine fishes			
a. Upstream spawning fishes			
1) River herrings	severely impaired	exploitation, habitat alteration, water quality	NCDMF, 2000; ASMFC, 1999.
2) Striped bass	impaired in most watersheds	exploitation, habitat alteration, water quality	ASMFC, 2002a; NCDMF 2002
3) Shads	impaired	exploitation, habitat alteration, water quality	ASMFC, 1999; NCDMF 2002
4) Sturgeons	severely impaired	bycatch, habitat alteration, water quality	ASMFC, 2000a
b. Fishes that use brackish nurseries			
1) American menhaden	abundant/threatened	exploitation, water quality	ASMFC, 2002b; NCDMF 2002
2) Spot, croaker, weakfishes and others	abundant/threatened	exploitation, water quality	ASMFC, 2002c, 2002d, 2002e; NCDMF 2002
3) Gag grouper	threatened	exploitation, water quality	SAFMC, 1998b
4) Black sea bass	impaired	exploitation, water quality	SAFMC, 1998b; ASMFC, 2000b
c. Resident estuarine fish communities			
1) Largemouth bass	abundant/threatened	water quality	
2) White perch	unknown	water quality	
3) Other species	unknown	water quality	
7. Estuarine reptiles			
a. Diamondback terrapin	threatened	bycatch, habitat alteration	LeGrand et al., 2001; Braswell, 1999
b. American alligator	threatened	habitat alteration	LeGrand et al., 2001; Braswell, 1999

ATTRIBUTE	STATUS	THREAT/CHALLENGE	MAJOR DOCUMENTS
<b>C. Marine Communities and Organisms</b>			
1. Marine Plants	abundant	exploitation potential	SAFMC, 2002
a. Sargassum			
2. Marine invertebrate communities	threatened	habitat alteration	SAFMC, 2003a; ASMFC, 2002f
a. Beach communities			
b. Reef communities	impaired	habitat alteration	SAFMC, 1998a
3. Marine fish communities (including for human consumption)	threatened	exploitation, habitat alteration, water quality	ASMFC, 2002g; NCDMF 2002
a. Surf fishes			
b. Reef fishes	severely impaired	exploitation, habitat alteration, water quality	SAFMC, 1998b; NMFS, 2002b; Musick et al., 2000
c. Highly migratory fishes			
1) Sharks	severely impaired	exploitation	NMFS, 2002a, 2002b, 1999
2) Tunas	threatened	exploitation	NMFS, 2002a, 2002b, 1999
3) Billfishes	threatened	exploitation	NMFS, 2002a, 2002b, 1999
4. Marine reptiles (sea turtles)	impaired/severely impaired	habitat alteration, bycatch	LeGrand et al., 2001; Braswell, 1989, 1999
5. Marine birds			
a. Colonial waterbirds	threatened	habitat alteration	LeGrand et al., 2001; ABC, nd
b. Beach-nesting birds	impaired	habitat alteration	LeGrand et al., 2001; ABC, nd
c. Oceanic seabirds	impaired	bycatch	LeGrand et al., 2001; ABC, nd
d. Shorebirds	abundant/threatened	habitat alteration	LeGrand et al., 2001; ABC, nd
6. Marine mammals			
a. Dolphins	impaired	accidental kills, bycatch	Marine Mammal Commission, 2001
b. Whales	severely impaired	exploitation, accidental kills, acoustics	Marine Mammal Commission, 2001
c. Manatees	severely impaired	accidental kills	Marine Mammal Commission, 2001
<b>II. Aquatic Ecosystem Functions</b>			
<b>A. Water quality in streams, lakes and rivers</b>			
1. Nutrient overenrichment	impaired	land management, waste disposal, air quality	NCDENR, 2002 (draft); NCDENR Basinwide Plans
2. Sedimentation	severely impaired	construction, land management, buffer integrity	NCDENR, 2002 (draft); NCDENR Basinwide Plans
3. Toxicants	impaired/threatened	waste disposal, land management, air quality	NCDENR, 2002 (draft); NCDENR Basinwide Plans
4. Pathogens	impaired	waste disposal, land management	NCDENR, 2002 (draft); NCDENR Basinwide Plans; NC DEH, nd
<b>B. Water quality in estuaries</b>			
1. Nutrient overenrichment	severely impaired	land management, waste disposal, air quality	NCDENR, 2002 (draft); NCDENR Basinwide Plans
2. Toxicants	impaired	waste disposal, land management, air quality	NCDENR, 2002 (draft); NCDENR Basinwide Plans
3. Pathogens	severely impaired	land management	NCDENR, 2002 (draft); NCDENR Basinwide Plans; NCDMF, 2001
<b>C. Riparian buffers</b>			
D. Flows in streams and rivers	impaired	land management, waste disposal, air quality	NCDENR, 2002 (draft); NCDENR Basinwide Plans; EnvDef, 2003
E. Groundwater quality	impaired	consumptive uses, impoundment, channelization	NC Div. Water Resources, 2001; SAFMC, 2003b
F. Availability of water for human consumption	impaired	agriculture, waste disposal, development, air quality	Wade et al., 1997; Dahlen and Milosh, 2002
		consumptive use, land management	NC Div. Water Resources, 2001
<b>III. Wetland Ecosystems</b>			
A. Overall wetland condition	impaired	land management, altered fire regime	USFWS, 1994; NCEDF, 1989; USFWS, 2000; Martin, et al., 1993a
<b>B. Forested wetlands</b>			
1. Tidal swamps (including fringe-wooded swamps)	threatened	rising sea level	Moorhead and Brinson, 1995; Schafale and Weakley, 1990
2. Bottomland hardwoods and swamps	impaired/threatened	forestry, flow regulation	Schafale and Weakley, 1990; NCNHP, 2003
3. Nonriverine wet hardwoods	severely impaired	forestry, drainage, agriculture	Schafale and Weakley, 1990; NCNHP, 2003; Schafale, 1999
4. Nonriverine hardwood swamps	threatened	forestry, drainage, rising sea level	Schafale and Weakley, 1990; NCNHP, 2003
5. Piedmont and mountain floodplains	impaired	forestry, agriculture, reservoirs	Schafale and Weakley, 1990; NCNHP, 2003
6. Upland depression forests	threatened	development, forestry	Schafale and Weakley, 1990; NCNHP, 2003

ATTRIBUTE	STATUS	THREAT/CHALLENGE	MAJOR DOCUMENTS
7. Atlantic white cedar forest	severely impaired	forestry, altered fire regime	Schafale and Weakley, 1990; NCNHP, 2003; USDAFS, 1997
8. Pocosins and pond pine woodlands	impaired	forestry, drainage, altered fire regime	Schafale and Weakley, 1990; NCNHP, 2003; Sharitz and Gibbons, 1982
9. Wet marl forests	severely impaired	forestry, drainage, development	Schafale and Weakley, 1990; NCNHP, 2003
10. Savannas and longleaf pine flatwoods	severely impaired	altered fire regime, land management	Schafale and Weakley, 1990; NCNHP, 2003
C. Marshes			
1. Saltmarshes	abundant	development, coastal engineering, rising sea level	Schafale and Weakley, 1990; NCNHP, 2003
2. Brackish marshes	abundant	development, rising sea level	Schafale and Weakley, 1990; NCNHP, 2003
3. Freshwater marshes	threatened	development, altered fire regime?	Schafale and Weakley, 1990; NCNHP, 2003
D. Bogs and Other Wetlands			
1. Mountain bogs and fens	severely impaired	agriculture, forestry	Schafale and Weakley, 1990; NCNHP, 2003
2. Piedmont bogs	severely impaired	agriculture, development	Schafale and Weakley, 1990; NCNHP, 2003
3. Carolina bays – ponds and cypress savannas	impaired	agriculture, altered fire regimes, altered regional hydrology	Schafale and Weakley, 1990; NCNHP, 2003
4. Vernal pools	severely impaired	development	Schafale and Weakley, 1990; NCNHP, 2003
5. Canebrakes	severely impaired	agriculture, forestry, altered fire regime	Schafale and Weakley, 1990; NCNHP, 2003
6. Lime sinks and other small depression ponds	impaired	development, altered regional hydrology	
IV. Upland Ecosystems			
A. Overall upland condition	severely impaired	land management, altered fire regime, invasives	Martin, et al., 1993b
B. Forests and woodlands			
1. Mountain			
a. Red spruce–Fraser fir forests	severely impaired	air pollution, climate change, alien insect invasion	Schafale and Weakley, 1990; NCNHP, 2003
b. Hemlock forests	threatened	air pollution, insect damage	Schafale and Weakley, 1990; NCNHP, 2003
c. Mountain pine forests	threatened/impaired	altered fire regime, pine beetles, forestry, development	Schafale and Weakley, 1990; NCNHP, 2003
d. Cove forests	threatened	forestry, development	Schafale and Weakley, 1990; NCNHP, 2003
e. Chestnut forests	severely impaired	alien fungus invasion, forestry, development	Schafale and Weakley, 1990; NCNHP, 2003
f. Oak forests	abundant	forestry (loss of old growth), development	Schafale and Weakley, 1990; NCNHP, 2003
g. Northern hardwood forests	abundant	forestry (loss of old growth)	Schafale and Weakley, 1990; NCNHP, 2003
2. Piedmont			
a. Piedmont longleaf pine forests	severely impaired	altered fire regime, land management	Schafale and Weakley, 1990; NCNHP, 2003
b. Monadnock forest	threatened	development, forestry	Schafale and Weakley, 1990; NCNHP, 2003
c. Xeric hardpan forests	impaired	altered fire regime	Schafale and Weakley, 1990; NCNHP, 2003
d. Oak-hickory forests	abundant, but greatly reduced	land management (loss of old growth), altered fire regime?	Schafale and Weakley, 1990; NCNHP, 2003
e. Piedmont moist slope forests	abundant	development, forestry (loss of old growth)	Schafale and Weakley, 1990; NCNHP, 2003
3. Coastal Plain and Sandhills			
a. Longleaf pine forests	severely impaired	altered fire regime, land management	Schafale and Weakley, 1990; NCNHP, 2003; Schafale, 1994
i. Red-cockaded woodpeckers	severely impaired	forestry, development	Schafale and Weakley, 1990; NCNHP, 2003
b. Mesic and dry hardwoods	impaired	land management	Schafale and Weakley, 1990; NCNHP, 2003
c. Maritime forests	severely impaired	development	Schafale and Weakley, 1990; NCNHP, 2003; Bellis, 1995
C. Herbaceous communities			
1. Piedmont prairie	severely impaired	development, agriculture, altered fire regime	Schafale and Weakley, 1990; NCNHP, 2003
2. Balds	impaired	unclear	Schafale and Weakley, 1990; NCNHP, 2003
3. Mountain and Piedmont rocky outcrops and glades	threatened	development, overuse for recreation	Schafale and Weakley, 1990; NCNHP, 2003
4. Dune and other beach grasslands	impaired	development, beach and dune engineering	Schafale and Weakley, 1990; NCNHP, 2003

ATTRIBUTE	STATUS	THREAT/CHALLENGE	MAJOR DOCUMENTS
V. Terrestrial Ecosystem Functions			
A. General forested landscapes	impaired	development, agriculture, intensive forestry	Wear and Greis, 2001
B. Migratory or highly mobile animals			
1. Butterflies and other insects	impaired/threatened	habitat alteration	LeGrand et al., 2001; Hall, 1999
2. Neotropical migrant songbirds	severely impaired/impaired	habitat alteration, distant habitat loss, feral and free-roaming pets	LeGrand et al., 2001; ABC, nd; Partners in Flight, 2000; USFWS, 2002a
3. Ducks, geese and swans	threatened	habitat alteration	USFWS, 2002b
4. Mourning dove	threatened	habitat alteration	Dolton and Holmes, 2002
5. Quail	severely impaired	habitat alteration	QU, 2002
6. Wild turkeys	impaired (increasing)	habitat alteration, prior exploitation	NC WRC, 2003c
7. Birds of prey	impaired	habitat alteration, prior shooting	LeGrand et al., 2001; ABC, nd; Partners in Flight, 2000; USFWS, 2002a
8. Wading birds and breeding colonies	threatened	habitat alteration	LeGrand et al., 2001; ABC, nd; Partners in Flight, 2000; USFWS, 2002a
9. Reptiles and amphibians (esp. pit vipers, frogs, salamanders)	impaired/severely impaired	habitat alteration, collecting for sale and export	LeGrand et al., 2001; Braswell, 1989, 1999; Braswell and Palmer, 1995
10. Bats	impaired	habitat alteration	LeGrand et al., 2001
a. Indiana bat	severely impaired	habitat alteration	LeGrand et al., 2001
11. Red wolf	extirpated/restocking	habitat alteration, prior exploitation	ASM, nd
12. Black bear	impaired (increasing)	habitat alteration, exploitation	NC WRC, 2003a
13. Cougar	extirpated?	habitat alteration, prior exploitation	ASM, nd
14. Elk	extirpated/restocking	habitat alteration, prior exploitation	ASM, nd
15. Deer	abundant	habitat alteration	NC WRC, 2003b
16. Foxes	abundant	habitat alteration	ASM, nd
17. Beavers	impaired (increasing)	habitat alteration, exploitation	ASM, nd; NC WRC, 2003e
18. Other small mammals	abundant to severely impaired	habitat alteration, feral and wild-roaming pets	ASM, nd
B. Agricultural production	abundant	development, reforestation	NCDA, 2002
C. Wood-based fiber production			
1. Native -- hardwood	impaired	softwood forestry	USDAFS, 1990; USDAFS nd
2. Noncultured -- softwood	impaired	cultured softwood forestry	USDAFS, 1990; USDAFS nd
3. Cultured softwoods	abundant	development	USDAFS, 1990; USDAFS nd
D. Soil building	impaired	agriculture, development	NRCS, nd
E. Internal ecosystem functions			
1. Pollination	inadequately quantified, but impaired	habitat alteration, toxicants	McGregor, 1976; Matheson et al., 1996
2. Animal food production (herbage, seeds, fruits)	inadequately quantified, but impaired	habitat alteration	
3. Habitat building and providing	severely impaired	land management	
4. Decomposition	inadequately quantified, but impaired	land management	
VI. Biomewide and Global Functions			
A. Air Quality			
1. Nitrogen Oxides (N and acid balance)	impaired	industry, automobiles	NRC, 2000a; NRC, 2000b; Galloway and Cowling, 2000
2. Sulfur Dioxide (acid balance)	impaired	industry	NRC, 2000a; Galloway and Cowling, 2000
3. Carbon Dioxide (greenhouse gases/climate)	severely impaired	power generation, automobiles	NRC, 2000c
4. Mercury	severely impaired	industry, power generation, waste disposal	US EPA, 1997
5. Total Particulate Matter	impaired	industry, power generation, waste disposal	US EPA, 2001
B. Overall Storing/Cycling of Nutrients	severely impaired	agriculture, industry, power generation, waste	NRC, 2000b; Galloway and Cowling, 2000
C. Detoxification and Decomposition of Wastes	inadequately quantified, but severely impaired	land management	
D. Spiritual Amenities			
1. Aesthetic	inadequately quantified, but impaired	land management, exploitation of resources	
2. Recreational	inadequately quantified, but impaired	land management, exploitation of resources	
3. Educational	inadequately quantified, but impaired	land management, exploitation of resources	

## REFERENCES

- Adams, W.F. 1990. A report on the conservation status of North Carolina's freshwater and terrestrial molluscan fauna. Scientific Council on Freshwater and Terrestrial Mollusks. 246 pp. + appendices.
- Adams, W.F. 1992. A report on the conservation status of North Carolina's freshwater and terrestrial crustacean fauna. Scientific Council on Freshwater and Terrestrial Crustaceans. 41 pp + appendices.
- Albemarle Pamlico Estuary Program. 1994. Comprehensive conservation and management plan. NC DENR and US EPA. 179 pp + appendices.
- American Bird Conservancy. nd. United States Bird Conservation Watchlist. ([http://www.abcbirds.org/watchlist/watchlist\\_list.htm](http://www.abcbirds.org/watchlist/watchlist_list.htm)).
- American Society of Mammalogists. nd. Mammals of North Carolina. (<http://www.mammalsociety.org/statelists/ncmammals.html>).
- Amoroso, J. L. 1997. Natural Heritage Program list of the rare plant species of North Carolina. NC Natural Heritage Program. 88 pp.
- Atlantic States Marine Fisheries Commission (ASMFC). 1999, 2000a-c, 2002a-c,g . Fishery management plans and periodic reviews for managed species (dates as given in the table).
- ASMFC. 2002f. Beach nourishment: a review of the biological and physical impacts. ASMFC Habitat Management Series #7. 174 pp.
- Bahr, L.M. and W.P. Lanier. 1981. The ecology of intertidal oyster reefs of the South Atlantic coast: a community profile. USFWS/OBS-81/15. 105 pp.
- Bellis, V. 1995. Ecology of maritime forests of the Southern Atlantic coast: a community profile. National Biological Service. Biological Report 30. 95 pp.
- Blair, R.B. 1996. Land use and avian species diversity along an urban gradient. *Ecological Applications* 6:506-519.
- Bock, Carl E., Jane H. Bock, and Barry C. Bennet. 1999. Songbird abundance in grasslands at a suburban interface on the Colorado high plains. *Studies in Avian Biology*, 19:131-136.
- Borawa, J.C., J.H. Mickey, C.J. Goudreau and M.M. Clemmons. 1998. Wild trout population monitoring, 1989-1996. NC Wildlife Resources Commission.
- Braswell, A.L. 1989. Scientific Council Report on the conservation status of amphibians and reptiles of North Carolina. 9 pp + appendices.
- Braswell, A.L. 1991. Scientific Council Report on the conservation status of North Carolina freshwater fishes. 17 pp + appendices.
- Braswell, A.L. 1997. Report of the Scientific Council on Amphibians and Reptiles on commercial trade. Report to the Nongame Advisory Committee, NC Wildlife Resources Commission. 27 pp.
- Braswell, A.L. 1999. Report by the Scientific Council on Amphibians and Reptiles on the updating of legal status listings. Report to the Nongame Advisory Committee, NC Wildlife Resources Commission. 29 pp.
- Braswell, A.L. and W.M. Palmer. 1995. Reptiles of North Carolina. Univ. North Carolina Press. 412 pp.
- Christensen, N.L. and twelve coauthors. 1996. The report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecological Applications* 6(3):665-691.

- Clamp, J.C. 1999. A report on the conservation status of North Carolina's freshwater and terrestrial crustacean fauna. Technical Report of the Scientific Council on Freshwater and Terrestrial Crustaceans.
- Dahlen, P.R. and R.M. Milosh. 2002. Impact of animal waste lagoons on groundwater quality: an update on data collected from March 1998 through November 1999. NC DENR. 99 pp.
- Daily, G.C and ten coauthors. 1998. Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues in Ecology of the Ecological Society of America. 17 pp. <http://www.esa.org/daily.htm>.
- DeCalesta, D.S. 1994. Effects of white-tailed deer on songbirds in managed forests in Pennsylvania. *Journal of Wildlife Management* 58: 711-718.
- DeLeo, G.A. and S. Levin. The multifaceted aspects of ecosystem integrity. *Conservation Ecology* vol. 1, no. 1:3, 1997.
- Dolton, D.D. and R.D. Holmes. 2002. Mourning dove population status, 2002. US Fish and Wildlife Service. 30 pp.
- Eaton, L. 2001. Development and validation of biocriteria using benthic macroinvertebrates for North Carolina estuarine waters. *Marine Pollution Bulletin* 42(1):23-30.
- Ewing, R., R. Pendall and D. Chen. 2002. Measuring sprawl and its impact. A Report of Smart Growth America.
- Fensin, E. and M.V. Borgh. 2000. 1999 algal bloom report. DENR. 16 pp.
- Galloway, J.N. and E.B. Cowling. 2002. Reactive nitrogen and the world: 200 years of change. *Ambio* 31,2:64-71.
- Hackney, C.T., S.M. Adams and W.H. Martin (eds.). 1992. Biodiversity of the Southeastern United States, Aquatic Communities. John Wiley & Sons, NY. 800 pp.
- Hall, S.P. 1999. Inventory of Lepidoptera of the Albemarle-Pamlico Peninsular Region of North Carolina, including Pettigrew, Goose Creek, and Jockey's Ridge State Parks and Nag's Head Woods Ecological Reserve. NC Natural Heritage Program. 74 pp.
- Hall, S.P. and M.P. Schafale. 1999. Conservation assessment of the southeast coastal plain of North Carolina, using site-oriented and landscape-oriented analyses. NC Natural Heritage Program. 250 pp.
- Herman, D.W and B.W. Tryon 1997. Land use, development and natural succession and their effects on bog turtle habitat in the southeastern United States. In: Proceedings – Conservation, Restoration and Management of Tortoises and Turtles – an International Conference, pp. 364-371, NY Turtle and Tortoise Society.
- Laerm, J., W.M. Ford and B.R. Chapman. 2000. Conservation status of terrestrial mammals of the southeastern United States. In: B.R. Chapman and J. Laerm (eds.), Fourth Colloquium on Conservation of Mammals in the Southeastern United States. Occasional Papers Number 12, NC Museum of Natural Sciences.
- LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran and M.J. Mac. 1995. Our living resources: a report to the nation on the distribution, abundance and health of US plants, animals and ecosystems. US Department of the Interior, National Biological Survey.
- LeGrand, H.E., S.P. Hall and J.T. Finnegan. 2001. Natural Heritage Program list of the rare animal species of North Carolina. NC Natural Heritage Program. 90 pp.
- Mac, M.J., P.A. Opler, C.E. Puckett-Haecker and P.D. Doran. 1998. Status and Trends of the Nation's Biological Resources, 2 vols. US Department of the Interior, US Geological Survey.

- Marine Mammal Commission. 2001. Annual Report to Congress. 236 pp.
- Marshall, M.D. 1995. North Carolina Oyster Restoration and Fishery Management Plan. NC Division of Marine Fisheries and NC Blue Ribbon Advisory Council on Oysters. 116 pp.
- Martin, W.H., S.G. Boyce and A.C. Echternacht (eds.). 1993a. Biodiversity of the Southeastern United States, Lowland Terrestrial Communities. John Wiley & Sons, NY. 528 pp.
- Martin, W.H., S.G. Boyce and A.C. Echternacht (eds.). 1993b. Biodiversity of the Southeastern United States, Upland Terrestrial Communities. John Wiley & Sons, NY. 373 pp.
- Matheson, A., S.L. Buchmann, C. O'Toole, P. Westrich and I.H. Williams (eds.). 1996. The conservation of bees. Academic Press. 254 pp.
- McGregor, S.E. 1976. Insect pollination of cultivated crop plants. USDA. Maintained as an updated virtual volume (<http://gears.tucson.ars.ag.gov/book/index.html>).
- MDC, Inc. 1986. Shadows in the sunbelt. Chapel Hill, NC.
- MDC, Inc. 2000. The state of the south. Chapel Hill, NC. 36 pp.
- Menhenick, E.F and A.L. Braswell. 1997. Endangered, threatened and rare fauna of North Carolina. Part IV. A reevaluation of the freshwater fishes. Occasional papers of the NC Museum of Natural Sciences and the NC Biological Survey, No. 11. Raleigh, NC 106 pp.
- Michener, W. K., E. R. Blood, K. L. Bildstein, M. M. Brinson, and L.R. Gardner. 1997. Climate change, hurricanes and tropical storms, and rising sea level in coastal wetlands, *Ecological Applications*, vol. 7, no. 3: 770-801.
- Moorhead, K.K. and M.M. Brinson. 1995. Response of wetlands to rising sea level in the lower coastal plain of North Carolina. *Ecological Applications* 5:261-271.
- Musick, J.A. and seventeen coauthors. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of salmonids). *Fisheries* 25 (11):6-30.
- National Marine Fisheries Service (NMFS). 1999. Our living oceans. Report on the status of US living marine resources. USDOC. NOAA Technical Memo. NMFS-F/SPO-41.
- NMFS. 2002a. Fisheries of the United States 2001. DOC/NOAA. 126 pp.
- NMFS. 2002b. Toward rebuilding America's marine fisheries. Annual report to Congress on the status of US fisheries – 2001. NOAA. 142 pp.
- National Research Council. 2000a. Acid deposition: atmospheric processes in eastern North America. National Academy Press. 375 pp.
- National Research Council. 2000b. Clean coastal waters: understanding and reducing the effects of nutrient pollution. National Academy Press. 428 pp.
- National Research Council. 2000c. Ozone depletion, greenhouse gases and climate change. National Academy Press. 136 pp.
- Natural Resources Conservation Service. nda. Inventory of erosion trends in North Carolina. (<http://www.nc.nrcs.usda.gov/ResConditions&Trends/Etrends.htm>).
- NRCS. ndb. Inventory of prime farmland in North Carolina. (<http://www.nc.nrcs.usda.gov/ResConditions&Trends/Pfland.htm>).

- NRCS. ndc. Inventory of cropland use in North Carolina. (<http://www.nc.nrcs.usda.gov/ResConditions&Trends/CropUse.htm>).
- Natural Resources Defense Council. 2001. Priority ocean areas for protection in the Mid-Atlantic. Findings of NRDC's Marine Habitat Workshop. 59 pp.
- NatureServe. 2002. States of the union: ranking America's biodiversity. Report for The Nature Conservancy, Arlington, Va. 25pp.
- North Carolina Department of Agriculture. 2002. North Carolina agricultural statistics, 2001.
- NC Department of Environment and Natural Resources (DENR). 1985. Assessment of surface water quality in North Carolina. Report No. 85-01.
- NC DENR. various dates. Basinwide management plans (for each of 17 river basins).
- NC DENR. 2001. Guide to the North Carolina Wetland Restoration Program's watershed restoration strategy. Version 1. 24 pp.
- NC DENR. 2002 (draft). Public Review Draft, North Carolina Water Quality Assessment and Impaired Waters List (2002 Integrated 305[b] and 303[d] Reports).
- NC Division of Environmental Health. nd. Conditionally approved shellfish harvesting areas database. (available through NC Center for Geographic Information and Analysis.)
- NC Division of Marine Fisheries (DMF). 2002. Stock Status of Important Coastal Fisheries in North Carolina, 2002.
- NC DMF. (various dates). Fishery management plans for various species (as given in table).
- NC DMF. 2001. North Carolina Oyster Fishery Management Plan. 217 pp.
- NC Division of Water Quality (DWQ). 1991. Biological assessment of water quality in North Carolina streams: benthic macroinvertebrate database and long-term changes in water quality, 1983-1990.
- NC DWQ. 2001. Annual report of fish kill events. NC DENR. 12 pp.
- NC DWQ. 2000. Fish kill events reported to the North Carolina Division of Water Quality during 2000. 7 pp.
- NC Division of Water Resources. 2001. State Water Supply Plan. 73 pp. plus appendices.
- NC Environmental Defense Fund. 1989. Carolina wetlands. Our vanishing resource. 89 pp + appendices.
- NC Environmental Defense. Fund. 1998. Soiled streams: cleaning up sediment pollution in North Carolina waters. Raleigh, NC. 73 pp.
- NC Environmental Defense. 2003. Riparian buffers: common sense protection of North Carolina's water. Raleigh, NC. 31 pp.
- NC Natural Heritage Program. 2003. Natural heritage database.
- NC Partners in Flight. 2001. A bird conservation plan for NC Partners in Flight: 2001-2005. 18 pp.
- NC Progress Board. 2001. NC 20/20 Report. 271 pp.
- NC Wetland Restoration Program. 2002. Annual Report. 27 pp.
- NC Wildlife Resources Commission. nda. The crayfishes of North Carolina. ([http://216.27.49.98/pg07\\_WildlifeSpeciesCon/ncrayfishes/index.html](http://216.27.49.98/pg07_WildlifeSpeciesCon/ncrayfishes/index.html))
- NC Wildlife Resources Commission. ndb. The North Carolina Atlas of Mussels and Endangered Fishes.

- NC Wildlife Resources Commission. ndc. North Carolina Black Bears. Big Game Facts.
- NC Wildlife Resources Commission. nde. North Carolina White-Tailed Deer. Big Game Facts.
- NC Wildlife Resources Commission. ndf. North Carolina Wild Turkeys. Big Game Facts.
- NC Wildlife Resources Commission. ndg. Beaver management in North Carolina. 13 pp. ([http://216.27.49.98/pg07\\_WildlifeSpeciesCon/pg7ffl.htm](http://216.27.49.98/pg07_WildlifeSpeciesCon/pg7ffl.htm)).
- Orr, D.M. and A. Stuart. 2000. The North Carolina Atlas: Portrait for a New Century. University of North Carolina Press. 461pp.
- Osborne, S. 1998. "Too Many Deer?" *Wildlife in North Carolina*, September: 16-19.
- Paton, P.W.C. 1994. The effect of edge on avian nest success: how strong is the evidence? *Conservation Biology* 8:17-26.
- Poff, N.L., M.M. Brinson and J.W. Day. 2002. Aquatic ecosystems and global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States. Report for the Pew Center on Global Climate Change. 44pp.
- Quail Unlimited. nd. Northern bobwhite conservation initiative fact sheet. Southeast Quail Study Group.
- Riggs, Stanley R. 2002. Shoreline erosion in North Carolina estuaries. North Carolina Sea Grant, Raleigh, NC.
- Schafale, M.P. and A.S. Weakley. 1990. Classification of the natural communities of North Carolina. Third Approximation. NC Natural Heritage Program. 325 pp.
- Schafale, M.P. 1994. Inventory of longleaf pine natural communities. NC Natural Heritage Program. 230 pp.
- Schafale, M.P. 1999. Nonriverine wet hardwood forests in North Carolina. Status and trends. NC Natural Heritage Program. 11 pp. (<http://www.ils.unc.edu/parkproject/nhp/nrwhf.html>).
- Schlesinger, W.H., J.S. Clark, J.E. Mohan, and C.D. Reid. 2001. Global environmental change: effects on biodiversity. In: M.E. Soule and G.H. Orians (eds), *Conservation Biology*, Island Press, pp. 175-223.
- Sharitz, R.R. and J.W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. USFWS/OBS-82/04. 93 pp.
- Soule, M.E. and G.H. Orians (eds). 2001. Conservation Biology: Research Priorities for the Next Decade, Society for Conservation Biology, Island Press.. 307 pp.
- South Atlantic Fishery Management Council (SAFMC). 1998a. Comprehensive Sustainable Fisheries Act Amendment.
- SAFMC. 1998b. Final habitat plan for the South Atlantic Region: essential fish habitat requirements for the fishery management plans of the South Atlantic Fishery Management Council. 719 pp.
- SAFMC. 2002. Fishery management plan for pelagic sargassum of the South Atlantic region.
- SAFMC. 2003a. Policy on beach dredge and fill activities and large-scale coastal engineering.
- SAFMC. 2003b. Policy on river flows.
- Southern Appalachian Assessment. 1996. Summary report. 118 pp.
- Stuart, A. 2000. The changing face of North Carolina: Mayberry no more. Report from Professor Emeritus, University of North Carolina at Charlotte. 26 pp.

- Taylor, C.A., M.L. Warren, J.F. Fitzpatrick, H.H. Hobbs, R.F. Jezerinac, W.L. Pfieger and H.W. Robison. 1996. Conservation status of crayfishes of the United States and Canada. *Fisheries* 21:25-38.
- Terborgh, J., L. Lopez, P. Nunez, M. Rao, G. Shahabuddin, G. Orihuela, M. Raiveros, R. Ascanio, G.H. Adler, T.D. Lambert and L. Balbas. 2001. Ecological meltdown in predator-free forest fragments. Science: vol. 294, no. 5548: 1923-1926.
- USDA Forest Service. 1990. Forest Inventory Analysis of North Carolina. (Also available by region: mountains, Piedmont, northern coastal plain, and southern coastal plain.)
- USDA Forest Service. 1997. Proceedings: Atlantic White-cedar: Ecology and Management Symposium. Technical Report SRS-27. 82 pp.
- US Environmental Protection Agency. 1992. National Water Quality Assessment Document.
- US Environmental Protection Agency. 1997. Mercury study report to Congress. (Eight volumes) EPA-452/R-97-003.
- US Environmental Protection Agency. 2001 (third external review draft). Particulate matter. Air quality review criteria for particulate matter. 2 vols. EPA/600/P-99/002aC and EPA/600/P-99/002bC.
- US Fish and Wildlife Service. 1994. Southeast wetlands. Status and trends, mid-1970s to mid-1980s. 33 pp.
- US Fish and Wildlife Service. 2000. Status and trends of wetlands in the coterminous United States 1986 to 1997.
- US Fish and Wildlife Service. 2002a. Birds of conservation concern, 2002. Division of Migratory Birds Management. 99 pp.
- US Fish and Wildlife Service. 2002b. Waterfowl population status, 2002. Department of the Interior. 51 pp.
- US Fish and Wildlife Service. (various dates). Recovery Plans for North Carolina Endangered Species. (individual plans for each, including among others: red wolf, Appalachian northern flying squirrel, etc.)
- US Global Climate Change Program. 2002. Preparing for a changing climate: the Potential Consequences of Climate Variability and Change – Southeast. Southeast Regional Assessment Team.
- Vitousek, P. J. Aber, R. Howarth, G. Likens, P. Matson, D. Schindler, W. Schlesinger, and D. Tilman. 1997. Human Alteration of the Global Nitrogen Cycle: Sources and Consequences. *Issues in Ecology* (7): 736-750.
- Wade, H., C. Bailey, J. Padmore, K. Rudo, B. Williams and A. York. 1997. The interagency study of the impact of pesticide use on ground water in North Carolina. North Carolina Pesticide Board. 112 pp.
- Warren, M.L. and eleven coauthors. 2000. Diversity, distribution and conservation status of the native freshwater fishes of the southern United States. *Fisheries* 25(10):7-31.
- Wear, D.N. and J.G. Greis. 2001 (draft). Southern forest resource assessment. USDA Forest Service. 98 pp.
- White, P. S., S. P. Wilds and G. A. Thunhorst. 1998. Southeast. In: M.J. Mac, P.A. Opler, C. E. Puckett-Haecker, and P. D. Doran (eds.). Status and trends of the nation's biological resources. 2 vols. U.S. Dept. of the Interior, U.S. Geological Survey, Reston, VA, pp. 255-314.
- Williams, J.D., M.L. Warren, K.S. Cummings, J.L. Harris and R.J. Neves. 1992. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18:6-22.
- Wright, D.H. 1987. Estimating human effects on global extinction. *International Journal of Biometeorology* 31:293-299.



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