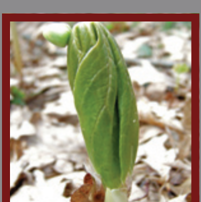
CHAPTER FOUR

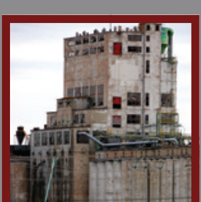
NATURAL HABITATS

Wisconsin Landscapes

Changes in Natural Habitats



Impacts and Vulnerabilities



Non-Climate Stressors

Adaptation Strategies

Photo: Darren Bush

AND BIODIVERSITY

Wisconsin is rich in natural resources. Our cultural identity and economy are tied to the wealth of species – both plants and animals – that inhabit our state. With 16 million acres of forested land, more than 1,800 native plant species, more than 500 terrestrial animal species, more than 80,000 miles of streams and rivers, and more than 800 miles of Great Lakes coastline, biological diversity abounds in our state. These varied and diverse natural resources serve vital roles both in their ecosystems, by providing benefits such as soil formation and water purification, and in our society, by providing aesthetic, economic and recreational value and by contributing to our food supply.

Climate change is impacting these ecosystems and their inhabitants by affecting individuals and communities of species and changing habitats and the processes that act within them. Rising temperatures, shifting precipitation patterns, and an increasing number of heavy rainfalls set off ripple effects that bring physical changes to natural habitats, triggering biological responses among the plant and animal species in them. Climate change is manifested differently across habitats, ecosystems and the state, with direct and indirect impacts resulting in "winner" and "loser" species, as some are particularly vulnerable to changes in climate and habitat while others are more resilient. While some species will indeed fare better in a warmer Wisconsin, scientists expect the majority of species influenced by climate change to fare worse.

In this chapter, we provide general descriptions of the northern and southern regions of the state, each with its own distinct geology, vegetation, wildlife and land use patterns; discuss the impacts of climate change on the natural habitats of these regions; and describe the vulnerabilities of various plant and animal species. This is the first assessment of climate change impacts on Wisconsin's natural habitats and biodiversity; therefore, these analyses are preliminary. As scientists continue to analyze the downscaled climate data, which are presented in Chapter 1, their findings about the climate impacts on natural habitats and biodiversity will be incorporated into future reports.

***Ecosystem**: Short for ecological system. A community of living organisms and its environment, considered together as a unit. Ecosystems are characterized by a flow of energy that leads to trophic structure and material cycling (that is, an exchange of materials between living and nonliving parts).*

Wisconsin Landscapes

Geography, geology and habitat types vary across Wisconsin. More than half of the landscape is forested, with agriculture taking a close second in percentage of land cover. The northern and southern regions of the state are divided by the Tension Zone (figure 1), a swath of land running northwest to southeast that marks the transition in vegetation, wildlife, geography and climate between these two regions of Wisconsin.

Northern Wisconsin

Northern Wisconsin is predominantly forested, characterized by a mix of conifers and hardwoods. Grasslands, agriculture and urban areas are present to a lesser extent. The region contains the headwaters for streams flowing north to Lake Superior, east to Green Bay and Lake Michigan, and south to small and large stream systems such as the Wisconsin and St. Croix rivers. Just south of the northern coastal region lie the lowland conifer forests of tamarack and spruce growing in ecologically diverse peat swamps.

An abundance of inland lakes, formed as the glaciers retreated to the north, dot the central portion of northern Wisconsin. Pines grow on the dry, sandy soils of the outwash plains among grasses, berries and lupine or along rivers and glacial lakes also populated with stands of hardwood trees such as maples and conifers such as hemlocks and balsam fir.

Tension Zone: *A transition zone that stretches across Wisconsin from northwest to southeast in an S-shape, forming the northern boundary of many species' ranges, both plant and animal. The Tension Zone divides the state into the two major ecological regions.*

The northeastern landscape contains the Lake Winnebago watershed, feeding Wisconsin's largest inland lake, as well as extensive wetlands, which are home to rare plant and animal species. The region is forested with an abundance of aspen and northern hardwoods. The species that inhabit the wetlands of the northern regions are very sensitive to temperature and water level changes, and the lakes are common nesting and breeding grounds for a diverse group of water birds, including common loons and black terns.

Southern Wisconsin

As we move southward through Wisconsin, geological conditions as well as temperature and moisture conditions change, leading to changes in landscapes, habitats and land use. Landscapes shift to agricultural fields, dotted with lakes and wetlands, remnants of prairies and savannas, and a mosaic of broadleaf forests of oak, hickory, maple and other species.

The central part of Wisconsin, known as the Central Sands, is mostly flat, punctuated by moraines and outcrops. This region is characterized by extensive

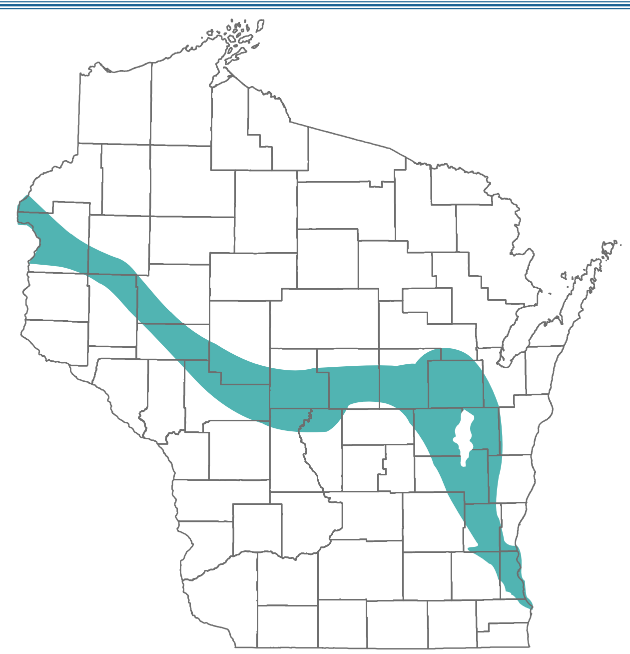
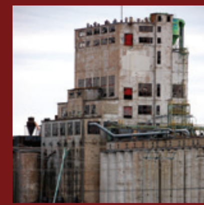


Figure 1. Tension Zone




wetlands and headwaters for coldwater streams, and the soils are sandy with some pine and oak forests. Agriculture dominates as the primary land use, and the region also supports forestry, cranberry production, recreation and wildlife management. The sandy soils and aquifers in the region make the system sensitive to variations in hydrology so that changes in groundwater levels can be pronounced and can quickly affect forests and other plant communities in both upland and lowland habitats. Rivers and floodplains provide extensive, contiguous habitats for many species and act as travel corridors, establishing connectivity with other ecological landscapes.

The western part of southern Wisconsin, known as the Driftless Area, was bypassed by glaciers during previous ice ages and is marked with ancient cliffs, deep valleys and steep hills that contain plant species – including glacial relict species – unique to the area. High ridges and valleys, with hardwood forests of oak, hickory, sugar maple and basswood, define the landscape. Agriculture is important here, and timber is harvested from the steep slopes. Many rivers, abundant in brook trout and brown trout, drain this region, forming wetlands as they join the Mississippi River floodplain.

The southwest – once mostly prairie and oak savannas – is now a mix of fields and pasture with sporadic oak trees spreading their limbs across the landscape. Coldwater streams are abundant. These grassland regions harbor many rare prairie and savanna plants as well as grassland birds, invertebrates and other animal species. Relict stands of hemlock grow along cool- and warmwater stream systems together with stands of hardwoods. Seventy percent of land in this region is used for agriculture.

In southeastern Wisconsin, glacial plains support a mix of urban and agricultural areas with occasional patches of forest. Large inland lakes, such as the Yahara chain in Dane County, Lake Geneva, Lake Koshkonong and others, dot the landscape; however, the ecosystems in this region have been degraded by deforestation, agriculture and urban development.

The northern Kettle Moraine – one of southern Wisconsin's major repositories of biodiversity, including many rare species – straddles the Tension Zone and features extensive forests, conifer and ash swamps, lakes, springs, marshes and a large stretch of the Milwaukee River. This area is an important refuge for bird species that live and nest almost exclusively within forests.

Coastal Regions

The Great Lakes coastline makes up a large portion of our state border. The wetland, bluff, beach and dune habitats differ from the rest of the state because the large water bodies of Lake Superior, Lake Michigan and Green Bay retain heat, creating "lake effect" microclimates. Lake Superior influences the temperature and precipitation patterns along its shores, creating microclimates with warmer winters and cooler summers compared to the rest of northern Wisconsin. These coastal habitats support a large number of rare plant and animal species. We discuss the climate change impacts on coastal regions and resources in the Chapter 6: *Coastal Resources*.

Habitat*: The place where an organism lives and its surrounding environment, including its living organisms and nonliving components (such as soil, rocks, air and water). Habitat includes everything an organism needs to survive.*

Changes in Natural Habitats

The distribution and abundance of each plant and animal species throughout the landscape is governed by its unique sensitivities to climate conditions, physical characteristics such as geology, soil type and topography, interactions with other species, and human activity. While from a human perspective we view natural communities as stable compositions, in the long term they are actually temporary associations of species subject to fluctuations in abundance and distribution as species respond to changes in their environments and climatic conditions.

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Photo: Jim Lorman

Physical changes in the environment, including those resulting from changes in climate, lead to an array of biological responses, some of which expose vulnerabilities and impacts within natural communities and habitats. While ecosystem responses to climate change are manifested differently across the varying habitats and ecosystems of the state, they do occur statewide. In the following sections we present some of the direct and indirect effects of climate change, the likely biological responses and the potential impacts and vulnerabilities.

Phenology: *The effect of seasonal cycle on biological phenomena such as flowering, breeding or migrating; the relationship between a regularly recurring biological phenomenon and climatic or environmental factors that may influence it.*

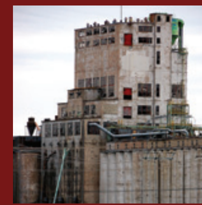
Early Onset of Spring

The earlier arrival of spring is one of many effects of climate change on the physical and biotic characteristics of Wisconsin's natural habitats and ecosystems. Across the state, temperatures are warming earlier in the year than in decades past. In the last 57 years, we have seen a statewide compression of the length of winter as spring weather arrives six to 20 days earlier than it used to, extending the growing season by two weeks. Trees are budding and flowers are blooming sooner, and the last of the ice is disappearing from the lakes earlier. Climate scientists and ecologists project this trend will continue.

These changes in growing season and the early onset of spring will affect the timing of life-cycle

Photoperiod: *The daily cycle of light and darkness that affects the behavior and physiological functions of organisms.*




BIRD MIGRATION	VEGETATION
Geese arrival: 29 days earlier	Baptista first bloom: 18 days earlier
Cardinal first song: 22 days earlier	Butterfly weed first bloom: 18 days earlier
Robin arrival: 9 days earlier	Marsh milkweed first bloom: 13 days earlier

Table 1. Evidence of earlier arrival of spring in Wisconsin from 1936-1998.

Source: Bradley et al., 1999. Phenological changes reflect climate change in Wisconsin. Proc. Natl. Acad. Sci., 96: 9701-9704.

events, or the *phenology,* of plants and animals. This means that the timing of biological events over the course of the year is shifting and will continue to shift for many species. Some plants and animals respond to temperature as a cue to initiate growth and reproductive activities, and others depend on photoperiod or respond to each other's life-cycle cues. These relationships may be thrown out of sync as climate change continues.

Migration behavior among wildlife is shifting in response to advances in signals of spring such as earlier snowmelt, warmer temperatures, more precipitation and other moisture signals. This shift is already in progress for some species in Wisconsin. In a recent study by Nina Leopold Bradley and others, researchers noted a shift in the phenology of 17 species in the state (table 1). One species, the Canada goose, now arrives a month earlier than in the 1930s and, according to the Wisconsin Department of Natural Resources, is now a year-round resident in southern portions of the state. In some instances, the phenological shift of a species may have cultural or economic implications. For example, year-round residence of the Canada goose may degrade water quality and increase damage to corn crops in the state.

Rising Water Temperatures

Temperature increases mean more than just warmer weather. As air temperatures rise, so will the temperature of water in streams, rivers, lakes and, to a lesser extent, groundwater.

Wisconsin is renowned for its abundance of coldwater streams that contribute to our state's cultural identity and legacy. These streams, which dissect the landscapes of northern Wisconsin and the western Driftless Area, provide fisheries for brook trout and brown trout. But these trout are very sensitive to changes in water temperature and can survive and reproduce only if temperatures remain below a certain threshold. For example, with an increase in the average summer air temperature of just over 5º F, models predict that rising stream temperatures could eliminate up to 95 percent of suitable brook trout habitat across the state.

Many warmwater species, including several game fish species such as channel catfish, smallmouth bass,

Migration*: The periodic seasonal movement of birds or wildlife from one geographic region to another, typically coinciding with available food supplies or breeding seasons.*

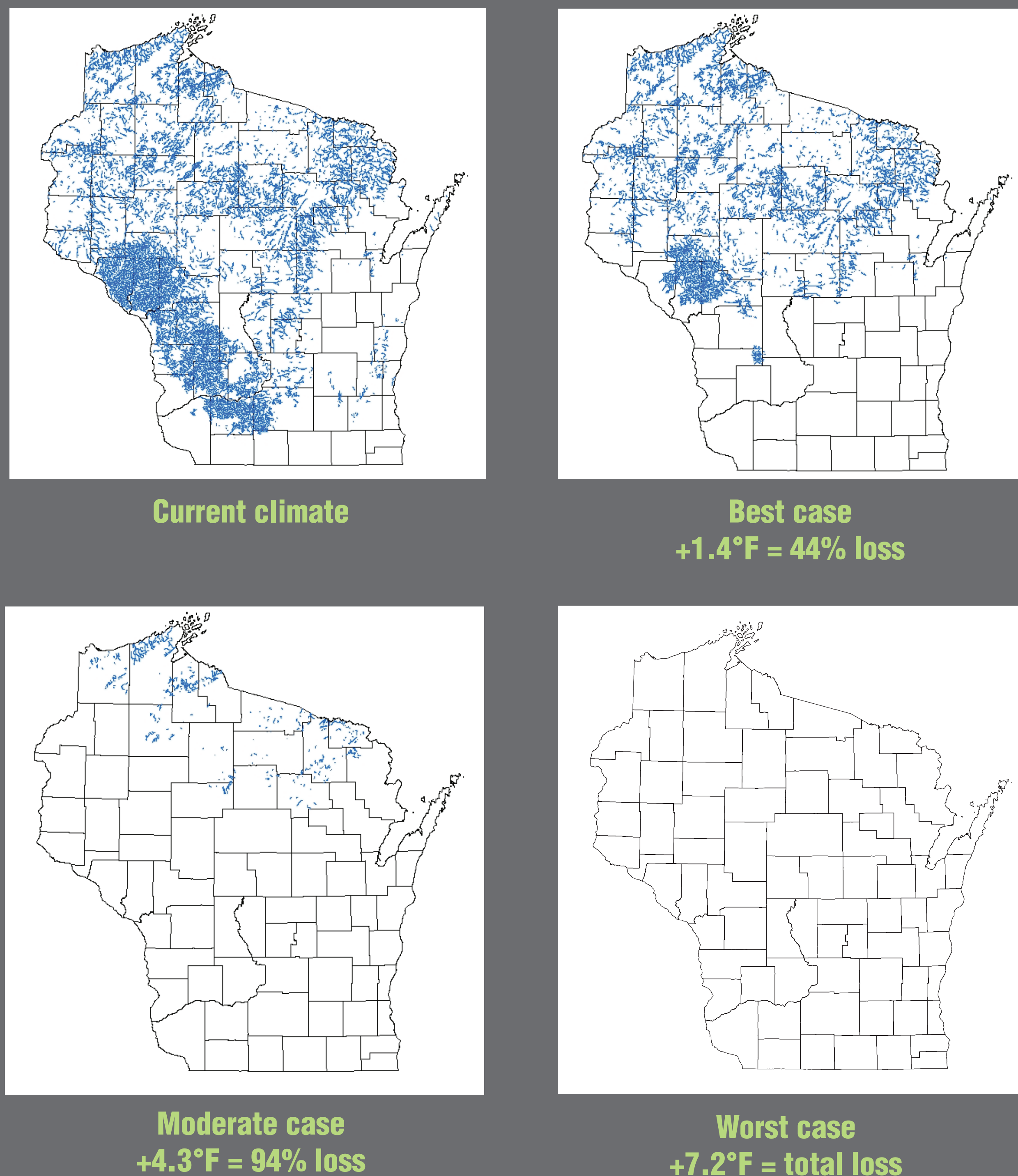
HOW WILL CLIMATE CHANGE IMPACT WISCONSIN'S BROOK TROUT?

Wisconsin is recognized for its abundance of coldwater streams, which includes more than 10,000 miles of classified trout streams. Anglers make a significant contribution to our local and state economies in their pursuit of trout and other coldwater fishes. Expected climatic changes across the state threaten the viability of Wisconsin's inland trout resources and the angling community that depends on them. The Coldwater Fish and Fisheries Working Group used watershed-scale models to predict the changes in coldwater habitat and distributions of coldwater fishes that would occur under three different climate change scenarios.

The working group ran models for each stream reach in the state under current climate conditions plus three mid-century climate warming scenarios projected for Wisconsin: 1) a "best-case" scenario (B1) in which summer air temperature increased by slightly more than 1.8° F and water temperature by 1.4° F; 2) a "moderate-case" scenario (A1B) in which air temperature increased by 5.4° F and water temperature by 4.3° F; and 3) a "worst-case" scenario (A2) in which air temperature increased by 9° F and water temperature by 7.2° F. The group analyzed the impacts on brook trout, brown trout, and mottled sculpin. The results show that climate change will likely cause reductions in all coldwater habitats and fish species in Wisconsin because increases in air temperature produce increases in water temperatures in nearly all coldwater streams. Brook trout are expected to take the biggest hit. Under the worst-case climate change scenario, brook trout are projected to be completely lost from Wisconsin streams. The moderate scenario brings a 94 percent loss, and even the best case leaves Wisconsin with 44 percent less brook trout habitat by mid-century. Under the worst-case scenario, brown trout habitat is expected to decrease by 88 percent, and mottled sculpin by 95 percent. The models show these losses occurring evenly across the state and not concentrated in any particular geographic region.

Differences in the characteristics of streams and their watersheds lead to variance in the capacity to buffer changes in water temperature from stream to stream. This brings opportunities for landowners and natural resource managers to offset the impacts on trout habitat through land, riparian and water management strategies, including stream restoration. A triage approach can help determine which streams may face inevitable losses of coldwater fishes and which streams could be maintained as viable trout habitat through the careful implementation of adaptation strategies. A proactive application of adaptation strategies will help protect Wisconsin's coldwater fishes and fisheries from the impacts of our changing climate. To learn more about the findings of the Coldwater Fish and Fisheries Working Group, see its full technical report at www.wicci.wisc.edu.

Photo: Matt Mitro



Predicted distribution of brook trout in Wisconsin streams under current climate conditions and predicted losses under three climate-warming scenarios for Wisconsin by mid-century.

Photo: Kathryn Kirk

Reduced snow cover threatens plant and animal species that are adapted to and rely on snow cover for their winter survival. Climate projections indicate that snow cover will drop by about 40 percent in northern Wisconsin over the next half century. Snow is a moisture source and a thermal insulator. For example, it provides an insulating cover for the fragile root systems of lowland conifers. Some wildlife, such as the American marten, rely on hollow trees and other areas in and under layers of snow for insulation and protection from predators. Less snow in future winters will present martens with greater risks of predation as well as more competition for their food resources.

largemouth bass and black crappie, will benefit from rising stream temperatures. And nongame fish, including various minnows and darters, will gain habitat as well. The length of stream habitat that warmwater fish are projected to gain, however, is three times less than the length of habitat coldwater fish stand to lose. Moreover, most of the coldwater streams that scientists expect to become warmer are too small to be suitable for warmwater game fish. This means that as these streams get too warm for coldwater game fish such as brook trout and brown trout, there will be no warmwater game fish that can fill the niche and provide a recreational fishery.

Fish are not the only wildlife that will be affected as stream temperatures rise. For example, Wisconsin is one of the few remaining states where the Hine's emerald dragonfly, a federally endangered invertebrate, is found. The dragonfly's larvae require ephemeral cool springs for development. As waters within their current distribution warm or increased rainfall prolongs wet conditions, the species may go extinct.

Reduced Snow and Ice Cover

With warmer temperatures during winter months, Wisconsin will see more of its winter precipitation falling as rain rather than snow, resulting in fewer days with snow on the landscape and ice cover on the lakes. These changes in winter precipitation will affect both plant and animal communities and will impact land and aquatic ecosystems.

Statewide, less snow cover during winter also increases opportunities for white-tailed deer to forage. More favorable conditions that provide deer with more time and land to forage will hurt native vegetation, forests and croplands.

Shorter winters will impact aquatic habitats as well. Invasive aquatic plants that respond to warm temperatures will get a head start earlier in the spring, becoming nuisances during the summer. There may come a time when Wisconsin's lakes are ice-free all winter, leading to extended growing seasons for aquatic plants and for blue-green algae, which could also lead to more frequent fish kills. We discuss shifting conditions in aquatic ecosystems in Chapter 3: *Water Resources*.

Freezing Rain

Predictions for warmer winters and more precipitation falling as rain rather than as snow suggest we will see an increase in freezing rain. While all trees and other plants face the threat of ice damage, conifer trees are particularly vulnerable. Because of their structure, with a single trunk and branches that extend from it, one break in the trunk can severely injure or kill a conifer tree. In contrast to hardwood trees, which have multiple thick stems branching from the main trunk, conifers respond poorly to breaks, which will be more prevalent when freezing-rain storms increase.

WINNERS AND LOSERS: WARM AND COLDWATER FISH

Many warmwater fish species, including several game fishes, will increase under climate warming, but overall, the increases in habitat occupied by warmwater species will be much less than the losses in habitat by coldwater and coolwater species. Scientists in the Coldwater Fisheries Working Group modeled the responses of 50 common stream fishes to three different climate change scenarios. Twenty-three species (all three coldwater species, all 16 coolwater species, and four of the warmwater species) were predicted to decline, with one coldwater and four coolwater species projected to vanish from the state's streams and rivers under a worst-case scenario, four warmwater species predicted to show essentially no change, and 23 warmwater species predicted to increase. According to the projections, the same number of species increased as decreased. Warmwater game fishes expected to increase are channel catfish, smallmouth bass, largemouth bass, and black crappie.

However, the average length of stream habitat lost by the 23 declining species was more than 20,000 kilometers per species, whereas the average amount of stream habitat gained by the 23 increasing species was only about 6,800 kilometers per species, again under the worst-case scenario. The declining species decreased by approximately three times more than the gaining species increased. Specific examples for game fishes, under the worst-case scenario, include:

Coldwater Brown Trout
losing about 33,000 km of habitat (-88 percent)

Brook Trout
losing about 29,000 km (-100 percent)

Coolwater Northern Pike
losing 11,000 km (-72 percent)

Walleye
losing 4,000 km (-88 percent)

Whereas:

Warmwater Channel Catfish
gaining 1,600 km (+32 percent)

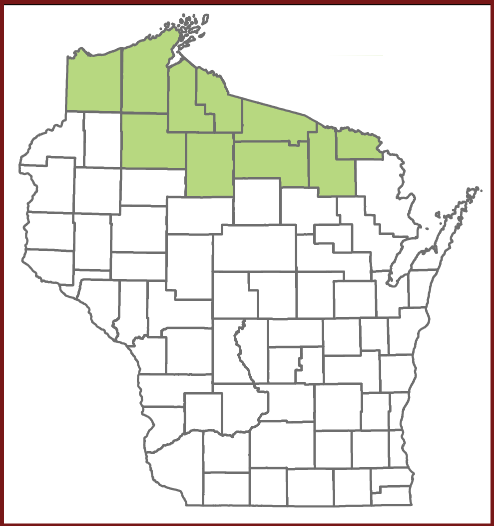
Largemouth Bass
gaining 7,000 km (+34 percent)

Most of the losses of cold and coolwater species will be in smaller streams that are now cold or cool but will become warm under climate warming. The gains for warmwater game fishes will occur in the relatively few medium-to-large cold and cool streams that will become warmer as climate continues to change. However, smaller trout streams, which are the vast majority of the state's trout waters, will not see lost trout being replaced by warmwater game fish. These streams may see some replacement by warmwater nongame species (various minnows and darters), but even then the replacement will be incomplete because dams and other barriers will prevent these warmwater nongame fishes from colonizing many of the new warmwater habitats created by climate warming.

THE AMERICAN MARTEN:
IMPACTS ON AN ENDANGERED MAMMAL IN WISCONSIN

The American marten is a small, carnivorous member of the weasel family. The marten was common in Wisconsin's northern forests until an intense period of timber harvest and trapping led to extirpation of the species from our state in 1939. Since the 1950s, the marten has been the subject of multiple reintroduction efforts, but despite those efforts, the marten was listed as endangered in the state in 1972. The few martens in Wisconsin currently live in the mature forests of Douglas, Bayfield, Ashland, Sawyer, Iron, Price, Vilas, Oneida, Florence and Forest counties.

The marten's low tolerance of snow-free conditions makes this species a good case study for climate change impacts. In the winters, it relies on areas underneath the snow for protection from extreme winter temperatures. Martens cannot survive Wisconsin winters without this thermal protection because their lean bodies have very minimal fat reserves for energy. Projected climate change in Wisconsin threatens to bring warming winter temperatures and more precipitation in the form of rain. Warmer temperatures mean more thawing and refreezing of the snow pack, which increases the density of the snow, and denser snow provides less thermal insulation for the marten. Snow cover is also expected to disappear earlier, exposing the marten to cold-weather conditions in the spring. The temperature, snow depth and snow density all influence the temperature of the subsurface areas that martens rely on, putting them in danger of death from energetic stress due to cold exposure.



Range of American marten.

The marten faces additional challenges as well. Rodents and other small mammals, the marten's food source, also rely on areas under the snow for protection from winter temperatures. Just like the marten, its prey will likely be threatened as the climate changes. Declines in the small mammal community will result in related declines in the marten population. This problem will be compounded by the fact that the marten's primary competitor, the fisher, hunts for the same small mammals. Climate change may lead to heightened competition between the two for resources, bringing negative impacts to both species. At this time, the long-term outlook for American martens in Wisconsin is uncertain and more research is needed to understand if and how we can preserve the Wisconsin population as the climate changes.

Reduced Soil Moisture

A warmer climate will likely result in a reduction of soil moisture. Hotter days – and more of them – will mean more evaporation and transpiration, and this includes water in the soil. Changes in soil moisture will affect plants, animals, and stream hydrology and habitats.

Drier soils can reduce the vigor of plants and their overall vitality. Trees and other plants require moisture to regenerate, and less moisture will make it more difficult for many plants to replace damaged cells.

Photo: Callen Harty

Forests such as the conifer lowlands, which are wet, boggy areas dominated by trees like tamaracks, black spruce and white cedar, depend on very moist soils. A reduction in soil moisture threatens the integrity of these forests and would lead to dead trees or even a gradual shift in the types of plants that grow in these regions.

Wildlife also will be affected by a reduction in soil moisture. Amphibians such as the American toad and eastern tiger salamander rely on humidity and moisture in the soil to maintain the water balance in their bodies. In warm, dry weather, they burrow underground to prevent dehydration. If soils dry out, these amphibians will die, impacting the rest of the forest ecosystem because they are an important food source for birds, reptiles and small mammals. Even a minor reduction in precipitation combined with high temperatures can cause rapid water loss in amphibians, and heat and water stress result in low survival rates.

Even a minor reduction in precipitation combined with high temperatures can cause rapid water loss in amphibians.

Less moisture in the soil also means less groundwater recharge to streams. When soils have adequate moisture, some of the water that falls as rain and soaks into the ground makes its way through the soil to recharge the base flow of rivers and streams. As air temperatures rise, so will stream temperatures, threatening populations of fish and insects that require cold water for their survival. This groundwater discharge helps buffer streams against increased temperatures. With reduced soil moisture, warming stream temperatures will worsen.

Drought

Even more extreme than the impacts that accrue from reductions in soil moisture is the threat of drought. While climate predictions project an overall increase in precipitation across the state, especially in the winter and spring, climate models are less certain about what will happen in the summers. More frequent or extreme periods of localized drought could impact a variety of habitats and natural communities, including water levels in lakes and wetlands, stream temperatures, forests and grasslands.

The north central part of Wisconsin contains a high concentration of the state's inland lakes. If temperatures rise and precipitation decreases in these areas, the resulting droughts will dry out wetlands and reduce habitat and nesting success for the diverse group of birds that inhabit these areas and amphibians that require wet conditions for suitable breeding sites.

Lakes in northern Wisconsin are currently receding, and the trend is projected to continue in future years.

Suitable nesting sites are becoming increasingly inaccessible to many birds. Loons, which typically nest within three to six feet of the water's edge because adults are not well-suited for movement on land, will have trouble coping with these reconfigured shorelines if drought conditions worsen.

Drought conditions can also make trees and other plants more susceptible to pests. For example, tamaracks require moist soils and are vulnerable to summer droughts. They already experience attacks from the tamarack bark beetle, but an increase in stress from droughts could reduce the trees' resilience, leaving them with little energy to combat the beetle.

While many trees and other plants will struggle to survive if drought conditions occur or persist, other species will fare better. For example, in northern Wisconsin, where drought conditions have persisted for about seven years through 2009, the rare native Fassett's locoweed is thriving. Some of these plant populations have exploded and seem – at least in the short term – to be benefiting from the dry conditions.

Flooding

While climate projections show a modest increase in precipitation across most of the state, they also include an increase in the magnitude and frequency of intense rainfall. More heavy downpours would increase the likelihood of flooding, which can damage or destroy habitats both in and outside of floodplains, essentially reestablishing floodplain boundaries. Soil conditions, the presence or absence of frost on the ground and land use affect the degree to which rainfall runs off or is absorbed into the soil, determining the extent of flooding.

After an intense rainfall event, streams and rivers often flood, saturating soils in the floodplain. Trees that grow in these areas, such as river-bottom hardwood trees including river birch and ash, cannot tolerate the saturated soils that come with prolonged flooding, and invasive plants such as reed canary grass grow in their place. Flooding also adds sediment, which covers struggling tree seedlings that cannot compete with the hardy canary grass.

Flooding could benefit other plant and animal species. Stinging nettles do well in floodplain forests, and if flooding results in new gaps in the forest canopy, vines like poison ivy, Virginia creeper and grapes will benefit. Annual native plants such as giant ragweed and jewelweed also respond well to flooding.

As for animals, trout can benefit indirectly from flooding, as they did after the floods of 2007 and 2008 in the Driftless Area. The heavy rainfall increased the base flow of many trout streams, creating a more suitable habitat for the fish. Amphibians, turtles and birds may also indirectly benefit from flooding if shallow depressions near streams capture water during floods or rain events, providing suitable habitat conditions for these species.

Species that inhabit both wetlands and grasslands are also vulnerable to flooding. In wetlands, increased flooding puts the fragile nests and habitats of many water birds at risk, and in grasslands, young birds such as the greater prairie chicken are very sensitive to rainfall and temperatures early in life because increases in heavy storms during the nesting season may chill or drown young birds.

Changing Lake Levels

As we discussed in Chapter 3: *Water Resources*, lake levels vary dramatically based on lake type and changes in precipitation and evapotranspiration. Higher temperatures and briefer periods of ice cover will result in more evaporation from lakes. Regional differences in soil type and land cover also will affect how climate changes translate into changes in lake levels.

Whether lake levels go up or down, the changes will affect components of aquatic habitats including plants, bottom materials like rock, sand or muck and coarse woody debris. Shallow lake systems will be most affected by lowered water levels, as would be the littoral zones – the areas extending from high water marks to a depth where light becomes limiting to rooted aquatic vegetation – of deep lakes.

Low lake levels leave important fish habitat, such as emergent vegetation and downed trees, out of the water along the shoreline. Human disturbance and removal of this habitat during times of low water could lead to permanent changes in ecosystem functioning. In contrast, high water conditions could result in redistribution of bottom materials and structural features to deeper water and could also uproot vegetation.

WHITE-TAILED DEER

The white-tailed deer is Wisconsin's official state wildlife animal and is the subject of an extensive harvest management program. Wisconsin deer hunting contributes $482 million annually to the state economy; conversely, large deer herds may damage crops and native vegetation by overgrazing, resulting in tens of millions of dollars in damage and alteration of native ecosystems. Given its influence on the local economy and native ecosystems, it is important to consider how a changing climate will influence Wisconsin's deer population.

As with many other species, winter survival for the white-tailed deer is a challenge. Extreme winter temperatures and snow depths are strongly associated with deer survival in northern forested regions of the state. Cold temperatures and deep snow lead to serious physical stress in deer because they must use a great deal of energy to keep warm and find substantial food in the snow. The result of such conditions can lead to high death rates in deer populations. By mid-century, the projected winter warming in Wisconsin (5-7° F in the southeast and 6-8° F in the northwest) will reduce this source of mortality in deer populations. Although winter precipitation will increase slightly by mid-century, more will be in the form of rain. More rain and warmer winter temperatures will reduce the duration of snow cover. Therefore, white-tailed deer will conserve energy and have easier access to food in Wisconsin's future climate, making winter survival much more likely. As deer abundance increases, wildlife managers will need to consider these changes in weather-related mortality and the potential impacts of larger deer herds on croplands, forests and native vegetation, especially in northern Wisconsin.

Photo: John Kubisiak, Sr.

It is also important to note that white-tailed deer populations may be exposed to more diseases as a result of changing temperature and precipitation patterns. For example, epizootic hemorrhagic disease (EHD) is an infectious viral disease common in white-tailed deer. The virus is transmitted by biting midges, primarily in late summer and early fall. Higher temperatures in winter and summer and lower precipitation in summer favor midge populations. These conditions match the future projections for Wisconsin's climate and it is reasonable to expect an increase in the frequency and/or severity of EHD. Wildlife managers will also need to consider the impacts of potential increases in disease outbreaks for white-tailed deer as a result of Wisconsin's changing climate.

Impacts and Vulnerabilities

Natural habitat conditions have never been static; rather, they change subtly over time, and the plant and animal species that inhabit them have evolved as conditions shift. But climate conditions are changing much more rapidly than in the past, and some species will struggle with adaptation at the current and projected future rates of change. Some species will have an easier time and will adapt to, and even benefit from, changes in their habitats. Others, however, will become increasingly vulnerable as they find their well-being and survival threatened by the responses of their habitat to climate change.

Edge of Range

Many native plant species in Wisconsin are at the edges of their continental distribution ranges. The northern part of the state has many plant species that are at the southern edge of their range, including those associated with boreal forest ecosystems. If temperatures continue to rise, the range of plant species currently growing in northern Wisconsin will shift northward out of the state, and the range of plants currently growing in states south of the border will expand into southern Wisconsin.

> Many native plant species in Wisconsin are at the edges of their continental distribution ranges.

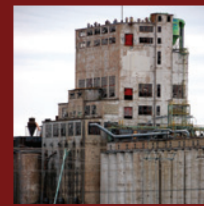
A warming climate will reduce suitable growing conditions for boreal forest species in Wisconsin. Birds and invertebrates within this ecosystem will be forced north, followed by tree and plant species. For example, by the end of the century, trees such as black spruce, balsam fir and paper birch will find their suitable remnant habitat in northern Minnesota or the upper peninsula of Michigan instead of Wisconsin. In addition, some boreal conifers host a species of lichen that grows only on those particular trees. If these conifers disappear from northern Wisconsin because of warming temperatures, so will the lichen, an important component of forest biodiversity. Tamarack lowlands are particularly at risk because they persist at the southern extent of their range and are sensitive to reductions in snow cover, which can allow the root systems to freeze without the insulating effects of the snow. However, some trees and other plants will benefit from warmer weather. Hardwood trees typical of the Midwest, such as hickory and black oak, will be winners in a warmer Wisconsin, expanding their range within the state as temperatures rise. There are also fish and wildlife living on the edge of their ranges. Wisconsin is at the southern edge of the national distribution of the native coldwater fish, brook trout. Where brook trout do occur south of Wisconsin, they do so in headwater streams. If their range shifts north as projected in response to rising air and stream temperatures, Wisconsin will lose most of its populations of brook trout.

***Distribution range**: The spatial arrangement of plant or animal species across the landscape.*

Changing Fire Regimes

Climate influences fire regimes in two ways: directly, by affecting weather patterns such as droughts, which are conducive to fire ignition and spread; and indirectly, by causing shifts in plant communities through temperature and precipitation changes that favor or discourage fire-adapted plant species. Changes in fire regime may be most apparent for the most fire-prone natural communities, particularly in landscapes that are not fragmented, such as the jack pine-dominated barrens in central and northwestern Wisconsin. Some




CLIMATE CHANGE AND THE WOOD FROG

The wood frog is a small amphibian that is widely distributed across the northeastern U.S. and Canada, including most of Wisconsin. It can endure winter in the coldest regions of the continent because it has a unique survival skill: it can freeze in winter and thaw when spring arrives. However, the lowest temperature wood frogs can endure is about 21º F, so they rely on soil burrows, leaf litter, and snow cover to buffer their bodies from Wisconsin's extremely cold winter temperatures. Once spring arrives, wood frogs also need temporary ponds close to woodlands in order to breed. Because of predation by fish, wood frogs are rarely found in permanent water bodies.

Climate conditions are critical to the wood frog's survival. In winter, snow cover provides thermal insulation from Wisconsin's cold temperatures. In summer, moist soils and leaf litter protect against rapid water loss, and temporary ponds provide suitable breeding sites. Given the frog's reliance on these conditions for survival, ecologists expect that projected climate changes will result in substantial impacts on the Wisconsin wood frog population, both in terms of where the frogs will be found and how many will survive.


Photo: Dan Nedrelo

Survival of juvenile wood frogs to reproduction age (about 2 years old) is the most important factor regulating the size of a population. A major cause of juvenile mortality is deep freezing when the frogs are exposed to extremely cold temperatures beyond their tolerance level. The projected reductions in snow cover for Wisconsin will put wood frogs at greater risk of dying from freezing before they are able to reproduce.

Another threat to wood frogs is water loss in hot, dry conditions. Under future climate scenarios, drought conditions are projected to increase in frequency, severity, and spatial extent around the globe, which will bring serious ramifications for amphibians. Wood frogs rarely travel more than a mile; therefore, they cannot move away from widespread drought conditions such as those northern Wisconsin has experienced in recent years. Wood frogs in this region of the state suffer from a high probability of death from water loss, particularly in hot summers. Drought conditions can also affect the number and condition of breeding sites for wood frogs. With changes in water levels from the predicted increased variability of precipitation, wood frogs will face more challenges in finding suitable breeding areas and will be unable to reproduce successfully. Moreover, under prolonged high temperatures there may be mass mortality of wood frog embryos.

In addition to reduced snow cover and drought, disease is an important consideration for amphibian populations, especially because changes in temperature may increase the prevalence and incidence of numerous amphibian diseases. For example, the growth of chytrid fungus, the pathogen associated with global extinction of some amphibian species, is regulated by temperature and moisture.

The wood frog is clearly vulnerable to our changing climate in a variety of ways. Accurate predictions for future populations of Wisconsin's wood frog require careful consideration of these and other factors likely to influence their survival and reproduction.

disturbance-dependent communities such as grasslands, sedge meadows, savannas, and barrens may benefit from more numerous fires, while other natural communities will fare worse.

Pollination Disruption

While some plants are pollinated by either wind or water, insects pollinate many other plants. These plants depend on their pollinators for survival. Changes in the timing of flowering caused by early spring temperatures may disrupt that relationship or eliminate those mutually beneficial interactions. For example, some spring flowers are opening earlier than in the past, when the flies and bees that pollinate them may not yet be present. In the southern upland forests, the suite of ephemeral herbs growing on the forest floor is likely to be moderately to highly affected by climate change because of interference in pollination. These herbs bloom and drop their seeds before the forest canopy has formed its leaves. They have a very short window for reproduction, and changes in the timing of pollination caused by changes in climate may adversely affect these species.

For specialist pollinators that are associated with certain plants, these relationships can be highly vulnerable to disruptions and can even present the threat of extinction. For example, the eastern prairie fringed orchid has only one known group of pollinators – the sphinx moths. If this endangered orchid blooms early and the moth is not on a similar life-cycle schedule, the pair will come uncoupled, making pollination unlikely.

Photo: Thomas A. Meyer

Shifting Species Composition

Warmer, wetter springs may affect some habitats more dramatically than others. For example, ice is melting off the lakes earlier, which means there is a longer growing season for algae, including toxic blue-green algae. The extent of wetlands may increase with wetter springs, but there may also be a shift to wetter, deeper wetland types associated with high water. Transitional wetlands that are more dependent on groundwater may decrease or be restricted to smaller areas because of increased evapotranspiration. Aquatic plant species that are adapted to cooler water temperatures may become scarce as temperatures rise.

When the temperature of a lake's water rises, there is a greater likelihood that species composition within the lake will shift. Increased temperatures may change the algal composition of the lake entirely, and increased algal growth reduces light penetration and clarity, making it more difficult for loons and other sight-feeding birds to locate food and for rooted aquatic plants to grow.

Higher water temperatures may also lead to increased blue-green algae growth. The algae deplete the lake's oxygen, resulting in dead zones. Some species of toxic blue-green algae can impair a water body, sickening swimmers, livestock or pets. An increase in nuisance levels of blue-green algae growth is more likely to occur in shallow, nutrient-rich lakes, many of which are found in the southern and southeastern parts of the state. A more thorough discussion of climate impacts on Wisconsin's water resources is presented in Chapter 3.

Species Mobility

The increased rate of climate change makes adaptation challenging for plants and natural communities that disperse their seeds over short distances. While plants with light, wind-spread seeds, such as orchids and asters, or those that are propagated by spores, such as ferns, mosses and lichens, may have a less challenging time keeping up with the rate of climate change, trees and other plants with larger, heavier seeds can take much longer to disperse. In some cases, the rate of climate change may exceed the rate at which species can disperse, and plant species with poor mobility – unable to expand northward to more suitable habitat – will die out.

***Dispersal**: The natural distribution of plant seeds and the offspring of organisms away from their area of origin or from centers of high population density over a wide area by various methods.*

Some wildlife species move across the landscape more easily than others. Although more mobile species can travel to more suitable climatic conditions, this is not an option for the eastern red-backed salamander. This species is considered a poor disperser. Because it is sensitive to water loss from exertion and exposure, its dispersal range is restricted to less than one mile. This situation poses a challenge to local populations. The eastern red-backed salamander must have viable habitat within that one mile in order to survive. Yet projected climate changes suggest that this salamander may be unable to colonize within a suitable climate niche, which can lead to local extinction. This fate is not unique to the eastern red-backed salamander; rather, it will be shared by many amphibian species and other poor dispersers.

Photo: Elizabeth Katt-Reinders

WILDLIFE RESPONSES TO CLIMATE CHANGE

SPECIES THAT MAY BENEFIT	SPECIES THAT MAY BE HARMED
CHARACTERISTICS	
Short generation times	Long generation times
Wide distributions	Narrow/restricted distributions
Move easily across landscape	Poor dispersal ability
Habitat generalists	Habitat specialists
Not sensitive to human activity	Sensitive to human activity
EXAMPLES	
Gray squirrel	American marten
White-tailed deer	Red-backed salamander
European starling	Spruce grouse
Canada goose	Common loon

Non-Climate Stressors

It is important to note that there are also nonclimate stressors that threaten biodiversity and habitat. These include habitat loss and fragmentation, invasive species and pollution. Climate change will interact with and exacerbate these stressors, intensifying and amplifying the challenges they pose to natural habitats and biodiversity.

Fragmentation and Habitat Loss

Fragmentation is the disruption of contiguous natural habitats into a patchwork of isolated natural areas surrounded by landscapes that are inhospitable to native vegetation and wildlife. Urbanization, land development and conversion of natural habitats to agricultural uses has broken up ecosystems so that there is no corridor or connected pathway through which they can travel. Plants and animals seeking to disperse and migrate to more suitable habitats as a result of climate change face the challenges of fragmented habitats and poor connectivity of suitable ecosystems. Fragmentation not only threatens the survival of animal populations but also impacts plant communities and their component species.

The combination of climate change and increased fragmentation is likely to affect species and natural communities statewide, both directly and through cascading effects. Many habitats in the southern portion of the state are already fragmented, leaving natural plant communities in that region more vulnerable to climate change. Forests and wetlands in the north and along the Great Lakes may be impacted to a lesser extent because of the presence of continuous habitat.

Fragmentation poses major challenges for plants dispersing their seeds. Species groups with poor dispersal abilities are expected to be more affected by rapid climate change than those that have the ability to migrate or disperse to suitable habitat. Long-distance seed dispersal is a rare but important occurrence that allows these fragmented species to maintain their populations, strengthening their resilience in the face of habitat disruption, climate change and other threats. Species that are able to disperse over long distance have an advantage over those that cannot as climate conditions shift habitat conditions, threatening fragmented habitats. Some groups of species, such as those with light or animal-dispersed seeds, may be better able to overcome the effects of fragmentation by colonizing scattered patches of suitable habitat via long distance dispersal. Often, however, these are weedy or invasive native and non-native species.

Invasive Species

Invasive species will have more opportunities to expand within or move into Wisconsin landscapes as climate change provides habitat conditions conducive to many of these species. Warmer winter temperatures may allow invasive species that are already established in southern and western Wisconsin to expand their ranges north. Species that lie to the south or west of the state border may invade and become established, bringing with them disease-causing organisms.

Climate change can promote the spread of invasive species in a number of ways. During flooding events, water bodies can become interconnected, allowing invasive species to spread from one lake to another. Wetter summers may reduce the effectiveness of purple loosestrife biological control organisms (weevils and leaf-eating beetles) in many wetlands, especially in kettle topography. Change in phenologies will require change in the timing of control efforts for this invader. In contrast, drought may open up new habitat that is well-suited for an invasive species.





Species not native to the area will be more likely to survive when temperatures rise because many species, such as kudzu, *Hydrilla*, water hyacinth or the red swamp crayfish, will be able to overwinter. These species are well-established in the southern United States and have been limited in Wisconsin by cold temperatures and ice cover. Recently, however, they have been found overwintering in small constructed ponds.

Native species*: Species that naturally occur within the community type; endemic to the area.*

Invasive species*: Species capable of rapid reproduction and spatial expansion, which may displace more specialized native species and/or are difficult to eradicate. Invasive species are of particular ecological concern if they are exotic, or introduced, to the area in question.*

Pollution

Regardless of climate change, pollution weakens the resilience of natural habitats. As climate change brings heavier rainfalls, polluted runoff from stormwater will increase, threatening ecosystem health. Runoff transports sediment, nutrients and chemicals from agriculture, industry and urban areas through our watersheds and natural habitats, polluting our waterways, wetlands and landscapes. If the projected increase in the magnitude and frequency of heavy rains occurs, we can expect to see the problem of polluted runoff worsen, increasing the threats to the health and vitality of Wisconsin's habitats and the species that inhabit them. Please see Chapter 3: *Water Resources* for a more in-depth discussion of stormwater runoff and water quality.


Photo: Andy Clark

Adaptation Strategies

The wide variety of natural habitats in Wisconsin and the biodiversity of the plant and animal species that inhabit them result in a wide range in the responses of species to climate change impacts. The variety of possible strategies for adaptation reflects the breadth and depth of climate impacts and vulnerabilities. In keeping with the organizational framework presented in Chapter 2: *Understanding Adaptation*, we present here several adaptation strategies relevant to Wisconsin's natural habitats and biodiversity. (Please see the Coldwater Fisheries, Forestry, Plants and Natural Communities, Water Resources and Wildlife Working Group reports at www.wicci.wisc.edu for a more detailed discussion of adaptation strategies.)

ADAPTATION

TAKING ACTION

Through proper stewardship, protected habitats can be maintained to promote the highest levels of natural resilience to change. The following principles are best practices for the goal of stewardship for ecological resilience:

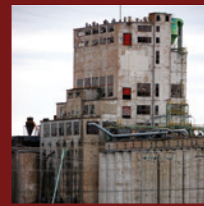
Adaptive Management

- Slow, managed change will be an important tool in helping managers cope with changing forest conditions. Forest managers already use a number of tools, policies and practices to ensure that the forests of Wisconsin are sustained into the future. These forest management tools and policies (such as invasive species management and assisted regeneration) can be valuable in reducing climate change impacts.
- Implement coastal and aquatic ecosystem management systems such as ecological buffer zones, open space preservation and conservation, ecosystem protection and maintenance, ecosystem restoration, creation, and enhancement, and aquatic invasive species management to support natural resilience.
- Utilize best management practices on agricultural lands, for example, implementing conservation tillage approaches to limit surface runoff or favoring rotational grazing over continuous grazing in riparian and upland areas of watersheds.
- Protect environmentally sensitive agricultural lands that provide wildlife habitat and water resource protection through enrollment in the Conservation Reserve Program or similar federal or state programs.
- Manage riparian vegetation to promote stream bank and channel stability, reduce erosion and siltation, and protect streams from damage from high-flow events. Provide shading to maintain the lower temperatures of groundwater input over longer lengths of coldwater streams.
- Adopt riparian and watershed land use practices that promote infiltration of precipitation and recharge of groundwater to maintain or enhance groundwater inputs to springs, ponds, and streams. Reduce existing, or limit creation of additional, impervious surfaces in critical watersheds containing coldwater streams, and utilize best runoff management practices in urban areas. Continue enforcement of laws governing groundwater use that are critical to protecting coldwater streams and trout fisheries from climate change.
- Manage fish population age structure to create resilience for interdecadal water level variability; determine minimum number of age classes needed for resilience.

Managing Cumulative and Synergistic Threats

- Northern Pike Fishery: Continue closed season for northern pike on tributary streams and daily bag limits; restore stream channels; manage




STRATEGIES

dam removal; manage water levels at restoration sites; continue emphasis on wetland acquisition, stream habitat and wetland restoration.

- Lake Sturgeon Fishery: Continue restricted harvest; ensure availability of spawning sites at dams under high- and low-water conditions through FERC licensing; protect hydrologic integrity of watershed of small rivers to maintain genetic diversity; reduce runoff of suspended solids; provide in-stream habitat improvement where possible and at critical sites.
- Wetland Habitat: Protect and restore integrity of wetland hydrologic regimes; consider seed bank manipulation to counter *Phragmites* invasions of exposed lakebed; control polluted runoff through pollutant load limits and runoff best management practices (particularly stream bank buffers); consider woody vegetation for stream buffers; protect sites by acquisition or conservation easement; evaluate existing conservation properties in a local and landscape context.

Approximating Natural Disturbance Regimes

- Establish and maintain corridors of contiguous habitat along natural environmental continuums to provide for migration and favorable conditions for local adaptation. An analysis of connectivity at landscape levels can identify important long-term opportunities for conservation actions.
- Assisted migration (relocating plants and animals geographically in anticipation of the projected climate change), while controversial, has the potential to facilitate long-term species survival.
- Restore prior-converted wetlands in upland agricultural areas to provide flood storage and runoff filtration, mitigating storm flows and nutrient loading downstream.
- Enhance and restore shoreline habitat (for example, coarse woody littoral and riparian vegetation or bio-engineered erosion control) to withstand variations in water levels.

BUILDING CAPACITY

- Use temperature and fish models to evaluate streams and their watersheds. Identify cold-water resources for protection and restoration, and allow for the evaluation of potential responses to climate change scenarios so that managers can make informed decisions when allocating management resources.
- Northern Pike Fishery: Examine zoning regulations for adequacy in protecting hydrologic integrity of both surface and groundwater of west Green Bay coastal zone.
- Lake Sturgeon Fishery: Develop innovations for passing fish upstream without passage of aquatic invasive species; develop census techniques for sturgeon ranging from juveniles to 10 years old.

(Adaptation Strategies continued)

- Use a triage approach to protecting coldwater streams from the impacts of climate change by setting realistic management expectations for success and evaluating possible climate change impacts on different coldwater streams. Use stream restoration techniques that promote colder water temperatures (for example, narrowing and deepening channels), and target restoration efforts to streams most likely to realize these benefits under a changing climate.
- Establish monitoring sites for forest ecosystems. These complex communities are most likely to see climate change impacts and will provide the means to track the rate of change, including changes in wildlife species, trees, shrubs and herbs.
- Wetland Habitat: Examine policies and regulations protecting lands below the ordinary high-water mark; policies need to be preemptive to protect. Identify, map, and prioritize potentially restorable wetlands in floodplain areas.

COMMUNICATING

- Build a stronger relationship with the public to establish a critical mass of ecological knowledge in the community. Assemble oral histories, photos, records, and studies to document previous conditions and present them to the public.
- Conduct a public review of state waterways and wetland regulation for adequacy in protecting coastal wetlands under a changing climate and in removing or modifying dams to allow for fish passage in response to changing stream conditions.
- Share results of vulnerability assessments and adaptive management strategies with other resource managers.
- Educate about the benefits of pollution load limits (total maximum daily loads, or TMDL) for reducing phosphorus and total suspended solids.


Photo: William Walker


Photo: Callen Harty

FILLING GAPS

- To reduce the amount of uncertainty in making decisions about resource allocations, conduct risk assessments of resource vulnerability to changing environmental conditions based on climate projections for individual species and natural communities. The assessments should be used in prioritizing management and other adaptation actions.
- Use climate analog models to identify other landscapes that currently have temperature and precipitation patterns similar to what Wisconsin's forests could experience in the future. Study the forest composition, disturbance, and pest and disease interactions of these sites to determine how Wisconsin's forests may respond in the future.
- Collect stream monitoring data (water temperature, flow, and fish abundance) to test predictions of the effects of climate change on the distribution of coldwater fish in streams and to determine how changes in air temperature and precipitation effect changes in stream temperature and groundwater input to streams.
- Increase the certainty of long-term precipitation and temperature trends and patterns to help forest modelers simulate climate-related changes in forests.
- For the Northern Pike Fishery: Assess the effect of lost submergent aquatic vegetation on predation and juvenile mortality; define relations between nutrient loading, water quality and sustainable spawning; determine the restoration potential of macrophyte habitat for juveniles.
- For the Lake Sturgeon Fishery: Assess the significance of egg predation on population; assess the success of downstream migrants passing over dams.
- Inventory wetland habitat fragmentation and connectedness and identify critical habitat for protection; assess the effectiveness of carp population control measures in protecting aquatic habitat.

Source material for this chapter was drawn from the Coldwater Fish and Fisheries, Forestry, Plants and Natural Communities and Wildlife Working Group reports, available online at www.wicci.wisc.edu.

Conclusion

Climate change is already impacting and will continue to impact natural habitats and communities. The current and projected rate of climate change is at least as rapid as past rates, and in many instances it exceeds the abilities of species to adapt. Some species will benefit at the expense of others, and natural resource managers and other stakeholders will need to determine their priorities to further develop robust adaptation strategies. Natural communities and ecosystems with greater biodiversity will fare better in the face of climate change than more homogenous ecosystems, and we will need to increase the resilience of ecosystems within structures that exist while enhancing our knowledge of climate change impacts.