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THE GARDENER'S GUIDE TO GLOBAL WARMING

CHALLENGES AND SOLUTIONS

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U.S. DEPARTMENT OF AGRICULTURE

NATIONAL WILDLIFE FEDERATION™

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FOREWORD

FOUNDED IN 1913, THE GARDEN CLUB OF AMERICA *has worked tirelessly over the years on behalf of plants, and is committed to preserving the worldwide system of biodiverse habitats and ecosystems that support them. The philosophy of the Lady Bird Johnson Wildflower Center is rooted in principles espoused by one of its founders, former First Lady Lady Bird Johnson, and is committed to conserving and restoring wildflowers, native plants, and the biological communities on which they depend. The Wildflower Center recognizes that the health and well-being of human communities is directly related to the health of the land which sustains human life.*

The Lady Bird Johnson Wildflower Center and The Garden Club of America speak as one voice in recognizing the serious reality of global warming and are further committed to preserving plant diversity worldwide. Biodiversity is the extraordinary variety and essential interconnectedness of living things that support life here on earth. Over the past several decades, our organizations have become deeply concerned over the escalating extinction of plant species and plant communities. We feel an important responsibility to increase the public's awareness and understanding of the many threats to plant biodiversity.

In 2006, The Garden Club of America, the Wildflower Center, and the National Park Service initiated *PlantWise (http://wildflower.utexas.edu/plantwise)*, an outreach program to educate gardeners about harmful invasive species, which contribute significantly to the loss of native species. We are so pleased that this National Wildlife Federation report will now be available to help gardeners understand the predicted impacts of global climate change on plant species, and also give them practical tools to address this urgent problem.

As the earth's climate changes, the habitats of many species will move poleward (northerly in the northern hemisphere) from their current locations. The most rapid changes are expected to occur in areas where natural ecosystems are already under stress from land development and other natural and anthropogenic disturbances. The impact of these shifts will not be limited to individual species; species that make up a plant community are unlikely to move together. It is more probable that species will respond to changing climate and disturbance regimes individualistically, with substantial time lags and periods of reorganization. This will disrupt established ecosystems and create new assemblages of species that may be less diverse, and include more invasive species. This will, in turn, increase the vulnerability of existing ecosystems.

There is a saying that the flapping of a single butterfly's wings can be felt around the world. It is also true that the cessation of that flutter is felt. We hope that this publication will help gardeners and others listen to the world a little more closely—to inspire them to hear and heed the flutters of life on our planet. It is incumbent upon each of us to find ways to be involved in improving the balance of life on earth. The science of climate warming is clear; we must act now, and we also must be prepared for a sustained, intense effort over many future decades. And finally, we must embark on this journey hopeful for success, not fearful of failure.

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JERRY PAVIA

WHETHER YOU HAVE JUST A FEW POTTED PLANTS ON THE BALCONY OR ACRES OF FLOWERS, FRUIT TREES, AND WATER FEATURES IN THE COUNTRY, THE GARDEN PROVIDES SOLACE AND IS A PLACE FOR PEOPLE TO CONNECT WITH NATURE AND ENJOY THE BEAUTY AND BOUNTY IT HAS TO OFFER.

SUMMARY

FOR MILLIONS OF AMERICANS, gardening is much more than a hobby—it is a passion. In 2005 alone, an estimated 91 million households participated in lawn and garden activities, spending more than $35 billion[1].

Whether you have just a few potted plants on the balcony or acres of flowers, fruit trees, and water features in the country, the garden provides solace and is a place for people to connect with nature and enjoy the beauty and bounty it has to offer. In many ways, our gardens are a window to the natural world around us.

Unfortunately, the view through that window is becoming increasingly clouded by global warming, which scientists have linked directly to human activities. In its most comprehensive assessment to date, the Intergovernmental Panel on Climate Change (IPCC) has found global warming to be "unequivocal" and states with unprecedented certainty that this warming is due to greenhouse gas emissions largely from our burning fossil fuels.

Unless we take significant action to reduce this global warming pollution, we will face more frequent and severe weather extremes, including heat waves, droughts, and floods; the expansion of harmful invasive species, pests, and diseases; the disruption of ecosystems; and the extinction of thousands of species—all of which are disasters for nature, let alone gardeners. Ultimately, failure to halt global warming will mean that the world we leave for our children and grandchildren will be vastly less supportive of the people, plants, and wildlife than the one we cherish today.

SOLUTIONS TO GLOBAL WARMING ARE IN GARDENERS' HANDS

Although the predictions for global warming are dire, they are not inevitable. Just as the IPCC projects serious consequences if we continue to emit greenhouse gases at the current rate, it also concludes that global warming and its impacts will be significantly lessened if we start now on a path to reduce our global warming pollution.

As gardeners, we are both guardians and stewards of our environment, and it is important for us to realize that there are many simple and thoughtful

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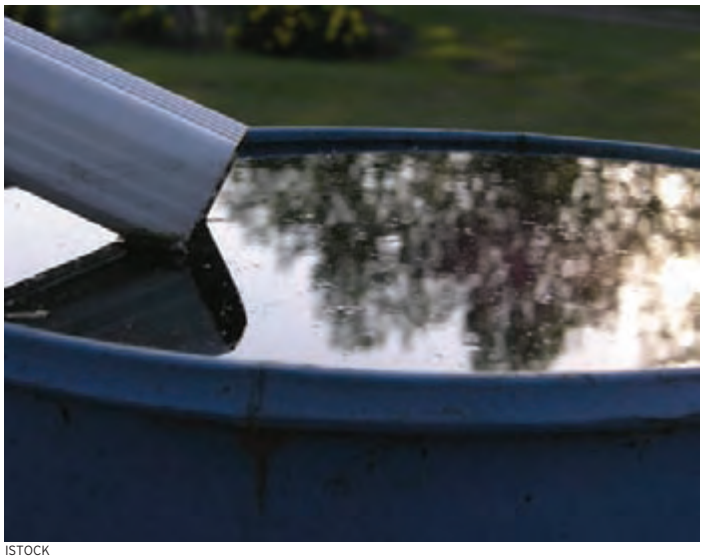
ways that we can work with nature to solve the problem. Through the following actions, we can make an enormous difference in our own backyards, in our communities, and in the way our government deals with this critical issue. In fact, we gardeners can take the lead in providing a healthy climate for our children's future.

Taking Action in Your Backyard

1. *Improve your energy efficiency.* One of the best ways to reduce your contribution to global warming pollution is to use more energy-efficient products and reduce your household's electricity and gasoline consumption. In your backyard alone, there are a number of actions you can take, including replacing regular outdoor light bulbs with compact fluorescent bulbs, installing outdoor automatic light timers, and purchasing solar-powered garden products.
2. *Reduce the use of gasoline-powered yard tools.* Another important change you can make is to avoid using gasoline-powered tools such as lawn mowers, weed eaters, and leaf blowers. Instead, use electric-powered or, better yet, human-powered tools such as push mowers, hand clippers, and rakes. If this seems daunting, you might consider replacing some of your lawn with low-maintenance groundcover or a native wildflower patch.
3. *Reduce the threat of invasive species expansion.* Gardeners can play an important role in minimizing the threat of invasive species expansion by removing invasive plants from the garden and choosing an array of native alternatives. Contact your local or state native plant society to find out what plants are native to your area.
4. *Incorporate a diversity of native plants into your landscape.* You can also help to maintain some of the important connections between pollinators and their hosts and ensure food sources for wildlife by incorporating a diverse range of native blooming and fruiting plants into your garden and having your yard recognized by the National Wildlife Federation as a Certified Wildlife Habitat™.
5. *Reduce water consumption.* There are a number of ways to reduce water consumption in your garden, which will be particularly important during heat waves and droughts when water resources become scarce. Actions can include mulching, installing rain barrels, adjusting your watering schedule, using drip irrigation, and xeriscaping.
6. *Develop a rain garden.* Gardeners can also reduce water pollution associated with heavy downpours by developing rain gardens, which capture stormwater runoff and help prevent it from entering local lakes, streams, and coastal waters.
7. *Compost kitchen and garden waste.* Composting kitchen and garden waste can significantly reduce your contribution to global warming pollution, especially methane, a highly potent greenhouse gas. It also provides an excellent source of



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nutrients for your garden, reducing the need for chemical fertilizers, which pollute water supplies and take a considerable amount of energy to produce.

8. *Establish a "greenroof" and plant trees to protect your house from the elements.* A "greenroof" is a roof that is covered by special soils and vegetation instead of shingles or tile. Planting a greenroof can significantly reduce stormwater runoff and help keep your home cooler in summer and warmer in winter, reducing energy costs. In addition, planting trees near your home can shield your home from the hot sun in the summer and cold winds in the winter, reducing energy use for air conditioning and heating.
9. *Plant lots of trees to absorb carbon dioxide.* As all gardeners know, growing plants absorb carbon dioxide (CO_2) from the atmosphere. As they grow to maturity, trees can absorb and store as much as a ton of CO_2, the greenhouse gas primarily responsible for global warming. If every one of America's 91 million gardening households planted just one young shade tree in their backyard or community, those trees would absorb around 2.25 million tons of CO_2 each year.

Taking Action in Your Community

1. *Connect places for wildlife by certifying your neighborhood as a Community Wildlife Habitat™.* By certifying your own backyard and encouraging your neighbors to do the same, you can turn your neighborhood into a Community Wildlife Habitat™, which can help maintain or reconnect fragmented habitats and provide ways for wildlife to better cope with the impacts of global warming.
2. *Participate in citizen science.* Another way for you to get involved is to participate in one or more "citizen science" programs across the country to help provide valuable scientific data to researchers while at the same time gain an opportunity to get closer to nature.
3. *Encourage local home and garden retailers to carry energy-efficient products.* You can help increase the availability of energy-efficient garden products, as well as native plants, by encouraging your local home and garden retailers to carry them.


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Actions for Your Elected Officials

In addition to implementing solutions in your backyards and communities, gardeners can play an important role in moving America toward a cleaner, safer, and more sustainable energy future by contacting your elected officials at the local, state, and federal levels and urging them to implement a strong plan of action to combat global warming. There are a number of meaningful actions for your government to take:

Federal government actions:

- Place mandatory limits on the nation's global warming pollution.
- Raise fuel economy standards for cars and sport-utility vehicles.

- Make bold investments in clean and efficient energy technologies and phase out coal and oil subsidies.
- Enact new standards for renewable power.

State government actions:

- Require utilities to generate a share of their electricity from renewable energy sources.
- Collect revenue from electric utility customers to fund sustainable energy programs.
- Allow customers with electric generating systems to sell unused electricity back to their local utility.
- Require stricter vehicle emissions standards and promote cleaner, advanced-technology vehicles.

Local government actions:

- Develop programs to curb suburban sprawl and promote urban "green space."
- Improve the energy efficiency of government buildings and motor vehicle fleets.
- Expand recycling programs.

WHY SHOULD YOU CARE?

The Threat of Global Warming

For the past 250 years, humans have been pumping tremendous amounts of CO_2 and other heat-trapping greenhouse gases into the atmosphere by burning coal, oil, and natural gas in our power plants, motor vehicles, homes, and factories. The buildup of these gases has caused a rapid increase in the earth's average surface temperature, and this global warming will continue to accelerate in the coming decades unless we significantly reduce the pollution causing it.

Global warming means far more than hotter temperatures. Left unchecked, global warming will rapidly and irreparably disrupt our planet's climate system, causing average temperatures and precipitation patterns to change and exacerbating weather extremes such as heat waves, heavy downpours, storms, and droughts.

Gardens and Backyard Wildlife
Sentinels of a Changing Climate

As many gardeners and backyard wildlife enthusiasts across the country have begun to notice, global warming is already having a significant impact on nature:

- Plants are leafing out and blooming earlier.
- Birds and butterflies are breeding and migrating earlier.
- Many wildlife species are shifting their ranges northward and to higher elevations.

These are major warning signals that global warming is upon us, and they are just the tip of the iceberg of what changes are ahead if we do not take meaningful steps now to curb our emissions of CO_2 and other greenhouse gases.

More Hassles for Gardeners, a Catastrophe for Nature

Changes in climate due to global warming will no doubt create some enormous new challenges for gardeners, given the strong relationship between our garden plants and climatic variables such as temperature and rainfall.

As numerous studies show, any potential benefits from a longer growing season will only be outmatched by a host of problems—from watering restrictions and damaging storms, to the expansion of unruly weeds, garden pests, and plant diseases.

Even more importantly, if our gardens are vulnerable to the impacts of global warming, imagine what it means for wildlife. With a garden, people can amend the soil, provide irrigation, and even create a more controlled climate for some plants by growing them in a greenhouse—subject, of course, to one's time and budget. But at least, to a certain extent, we have those management options. In nature, any opportunities to manage these systems on any major scale are limited at best.

Expansion of Invasive Species, Pests, and Diseases

Global warming will contribute to a considerable expansion of invasive, nonnative plants and animals, which are able to take advantage of weakened ecosystems and outcompete native species. Higher average temperatures and changes in precipitation patterns will enable some of the most problematic species, including kudzu *(Pueraria montana var. lobata)*, garlic mustard *(Alliaria petiolata)*, purple loosestrife *(Lythrum salicaria)*, and Japanese honeysuckle *(Lonicera japonica)*, to move into new areas.

In addition, global warming will contribute to more severe infestations and habitat damage from both native and exotic insect pests, including black vine weevil *(Otiorhynchus sulcatus)*, gypsy moth *(Lymantria dispar)*, bagworm *(Thyridopteryx ephemeraeformis)*, and mountain pine beetle *(Dendroctonus ponderosae)*. Drought-stricken plants are also more susceptible to diseases.

Threats to Native and Iconic Species: No More Ohio Buckeyes in Ohio?

Shifts in average temperatures, precipitation patterns, and other changes due to global warming will mean that many native and iconic plants may no longer find suitable climate conditions in major portions of their historic range. In fact, many states across the country may lose their official State Trees and State Flowers. Imagine Kansas without the sunflower *(Helianthus annuus)* and Ohio without the Ohio buckeye *(Aesculus glabra)*!

Disrupted Ecosystems and Species Extinctions

Furthermore, as diverse species respond to global warming in different ways, important connections between pollinators, breeding birds, insects, and other wildlife and the plants on which they depend will become disrupted.

Butterfly caterpillars may hatch before the leaves of their foodplants are present. Pollinators such as hummingbirds and bees may arrive either too early or too late to feed on the flowers on which they normally rely. And birds may migrate in spring only to find that the insects, plants, or other foods they eat are not available.

Making matters worse is that global warming will fall on top of the many other serious problems facing plants and wildlife. Increasingly fragmented habitats will make it much more difficult, if not impossible, for species to move to find more favorable conditions. Ultimately, the more global warming pollution we allow to build up in the atmosphere, the greater the risk that we will disrupt ecosystems to the point of collapse and drive countless species to extinction.

CONCLUSION

Fortunately, solutions are readily at hand. Everyone can play an important role in combating global warming, restoring and protecting native species and habitats, and ensuring that the plants, animals, and other wonderful things our natural world provides us will endure for our children's future and, in fact, generations to come.

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JUST HOW SEVERE THE IMPACTS OF GLOBAL WARMING WILL BE IN OUR OWN BACKYARDS AND AROUND THE WORLD DEPENDS IN LARGE PART ON THE DECISIONS WE MAKE TODAY. FORTUNATELY, OUR GARDENS ALSO PROVIDE US WITH AN IMPORTANT OPPORTUNITY TO FORWARD MEANINGFUL SOLUTIONS.

GARDENERS—SOLUTIONS TO GLOBAL WARMING ARE IN YOUR HANDS

GARDENS PROVIDE PEOPLE WITH A SPECIAL CONNECTION to our natural world, and that world is sending us a strong warning of the challenges that we face if we fail to take effective action to combat the serious, potentially devastating threat of global warming.

By relying so extensively on burning fossil fuels to meet our energy needs, humans have caused tremendous amounts of carbon dioxide (CO_2) and other heat-trapping greenhouse gases to build up in the earth's atmosphere. This buildup has been causing our planet to heat up, disrupting the entire climate system.

Just how severe the impacts of global warming will be in our own backyards and around the world depends in large part on the decisions we make today. Fortunately, our gardens also provide us with an important opportunity to forward meaningful solutions. With the simple yet thoughtful actions highlighted in this report, we can significantly reduce our personal contribution to global warming pollution and benefit our environment in many other ways in the process.

Taking Action in Your Backyard

1. Improve your energy efficiency.

One of the best ways to lessen your contribution to global warming pollution is to use more energy-efficient products and reduce your household's electricity and gasoline consumption. In your backyard alone, there are a number of actions you can take:

- *Replace regular light bulbs with compact fluorescent bulbs.* If every American household replaced just one regular incandescent light bulb, either outside or in, with an Energy Star®–rated compact fluorescent bulb, it would prevent more than 11.5 billion pounds of CO_2 emissions—enough pollution equivalent to removing nearly a million cars from the road.[2]
- *Install outdoor automatic light timers.* Installing a timer can cut your outdoor lighting energy use by up to half. You won't have to remember to turn your outdoor lights on in the evening and off during the day. Or consider using motion detectors that switch on automatically when people or wildlife move close to them and switch off after a few minutes.[3]
- *Purchase solar-powered garden products.* There are a number of solar-powered lights and fountains available that recharge each day and don't require the installation of extensive wiring throughout your garden beds. You can also install solar panels to provide power for your garden shed or garage.

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2. Reduce the use of gasoline-powered yard tools.

Another important change you can make is to avoid using gasoline-powered tools such as lawn mowers, weed eaters, and leaf blowers. According to the U.S. Environmental Protection Agency, 54 million Americans mow their lawns each weekend, using 800 million gallons of gasoline in the process. In fact, using one gasoline-powered mower for an hour pollutes as much as 40 late-model cars; and weed eaters and leaf blowers pollute even more.[4] Instead:

- *Use electric-powered or, better yet, human-powered tools.* Tools such as push mowers, hand clippers, and rakes can significantly reduce the amount of global warming pollution we put into the atmosphere—and provide a great way to get some exercise!
- *Consider reducing the amount of lawn area.* Replacing lawn with attractive, low-maintenance plants that are native to your area can minimize the amount of mowing you will need to do and provide better habitat for wildlife than sod.

3. Reduce the threat of invasive species expansion.

The plants, animals, and other living organisms in nature are connected to each other and their environment, and they have adapted and evolved over time to support dynamic but stable ecosystems. Unfortunately, many of the earth's ecosystems are being been disrupted by human activities, and their ability to support people and wildlife alike is at risk if we fail to take a more concerted effort to protect them.

One of the ways people are harming ecosystems is by introducing nonnative ("exotic") species into places that are outside of their natural habitat range. In fact, many of the most popular garden plants are exotic species, brought in from another part of the country or from places around the world.

Although not all exotic species cause problems for native ecosystems, a number of nonnative plants have become highly invasive in their new surroundings, outcompeting native species and turning diverse ecosystems into virtual monocultures. With global warming, some of the most harmful invasive species in the United States, including purple loosestrife *(Lythrum salicaria)*, Japanese honeysuckle *(Lonicera japonica)*, and English ivy *(Hedera helix)*, are expected to gain even more of a foothold.

Gardeners have an important role to play to minimize the threat of invasive species expansion by removing invasive plants from the garden and choosing an array of native alternatives. For example, the USDA Forest Service has identified a number of plant options for gardeners to consider as substitutes for some of the worst invasive plants *(see Table 1)*.

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TABLE 1. Examples of harmful exotic plants and native alternatives

SOME HARMFUL INVASIVE GARDEN SPECIES LIKELY TO BENEFIT FROM GLOBAL WARMING	BETTER NATIVE ALTERNATIVES FOR YOUR GARDEN
English ivy *(Hedera helix)*	Plantain-leaved sedge *(Carex plantaginea)*, marginal woodfern *(Dryopteris marginalis)*, white woodland aster *(Eurybia divaricata)*, Meehan's mint *(Meehania cordata)*, creeping phlox *(Phlox stolonifera)*
Purple loosestrife *(Lythrum salicaria)*	Purple coneflower *(Echinacea purpurea)*, gayfeather *(Liatris spicata)*, shaggy blazing star *(Liatris pilosa)*
Oriental bittersweet *(Celastrus orbiculatus)*	American bittersweet *(Celastrus scandens)*, Virginia rose *(Rosa virginiana)*
Porcelainberry *(Ampelopsis brevipedunculata)*	Gray dogwood *(Cornus racemosa)*, Virginia creeper *(Parthenocissus quinquefolia)*, swamp haw viburnum *(Viburnum nudum)*
Japanese honeysuckle *(Lonicera japonica)*	American wisteria *(Wisteria frutescens)*, leatherflower *(Clematis viorna)*, Carolina jasmine *(Gelsemium sempervirens)*, trumpet honeysuckle *(Lonicera sempervirens)*, sweetbay magnolia *(Magnolia virginiana)*, purple passionflower *(Passiflora incarnata)*

SOURCE: Data from USDA Forest Service, "Kick the Invasive Exotic Gardening Habit with Great Native Plant Alternatives," http://www.fs.fed.us/wildflowers/nativegardening/alternatives.shtml (accessed 7 November 2006).

TABLE 2. Native plant options for hummingbirds

	SEASON		
REGION	SPRING	SUMMER	FALL
Northeast	Red columbine *(Aquilegia canadensis)*	Scarlet beebalm *(Monarda didyma)*	Cardinal flower *(Lobelia cardinalis)*
Southeast	Trumpet honeysuckle *(Lonicera sempervirens)*	Woodland pinkroot *(Spigelia marilandica)*	Trumpet creeper *(Campsis radicans)*
Midwest	Red buckeye *(Aesculus pavia)*	Royal catchfly *(Silene regia)*	Wild bergamot *(Monarda fistulosa)*
Western Mountains	Twolobe larkspur *(Delphinium nuttallianum)*	Giant red Indian paintbrush *(Castilleja miniata)*	Firecracker penstemon *(Penstemon eatonii)*
Pacific Northwest	Flowering currant *(Ribes sanguineum)*	Silvery lupine *(Lupinus spp.)*	Fireweed *(Chamerion angustifolium)*
Southwest	Ocotillo *(Fouquieria splendens)*	Crimson sage *(Salvia henryi)*	Scarlet gilia *(Ipomopsis aggregata)*

For a list of what plants are native to your particular area, contact your local/state native plant society. The following web sites may also be helpful:

- Lady Bird Johnson Wildflower Center, *http://www.wildflower.org*
- New England Wildflower Society, *http://www.newfs.org/nps.htm*
- PlantNative, *http://www.plantnative.com*

4. Incorporate a diversity of native plants into your landscape.

As diverse species respond to global warming in different ways, important connections between pollinators, breeding birds, insects, and other wildlife and the plants on which they depend will become disrupted. Although some species may have the ability to move or adjust their behavior with a changing climate, there are others that cannot change, may do so at a different rate, or respond to cues other than climate, such as the length of the day.

You can help maintain some of the important connections between pollinators and their hosts and ensure available food sources for wildlife by incorporating a diverse range of native plants whose bloom times overlap. That way, if some plants succumb to extreme events such as heat waves, there is a greater likelihood that some important plants will still be available to support wildlife.

U.S. FOREST SERVICE/JOSEPH M. SCHNEID

In addition, you can ensure that food sources will be available throughout the year by choosing plants with a range of blooming or fruiting schedules.[5] For example, Table 2 *(on page 11)* identifies some native plant options that provide excellent sources of nectar and insects for hummingbirds in spring, summer, and fall.

You can also help backyard wildlife survive by providing undisturbed places for nesting, hibernation, and overwintering in the garden landscape and supplementing available water and food sources. The National Wildlife Federation's Certified Wildlife Habitat™ program offers a number of suggestions for turning your garden into a true haven for birds, butterflies, amphibians, and other wildlife. (Visit *www.nwf.org/gardenforwildlife* to learn more.)

5. Reduce water consumption.

In many parts of the country, more severe heat waves, droughts, and declining snowpack due to global warming will cause a considerable reduction in available water resources. Reducing your water consumption and freeing up water supplies for other uses is a critically important way for gardeners to deal with the impacts of global warming. There are a number of things you can do that will make a difference:

- *Place mulch in your garden beds.* The simple act of mulching can help conserve water and moderate soil temperatures for plants. As mulch breaks down, it also provides nutrients to the soil, reducing the need for fertilizers that not only contribute to water pollution but often take significant amounts of fossil fuels to produce.
- *Install rain barrels.* Rain barrels are used to collect rainwater for use during dry months. Besides conserving water, an obvious reason for harvesting rainwater is to save money. Depending on the size of your house and the amount of rainfall in your area, you can collect a substantial amount of rainwater with a simple system.[6]

- *Adjust your watering schedule.* By watering your garden early in the morning or late in the afternoon, you can minimize the amount of water that would evaporate in the midday sun.
- *Use drip irrigation.* Installing a drip irrigation system or using soaker hoses are much more efficient ways to water your garden than sprinklers.
- *Practice xeriscaping.* Xeriscaping is an approach to landscaping that minimizes outdoor water use while maintaining soil integrity through the use of native, drought-tolerant plants.[7]

6. Develop a rain garden.

At the same time global warming is contributing to more extensive drought conditions in many parts of the country, it is also causing heavier rainfall events. This means more stormwater runoff and associated pollution in lakes, streams, and coastal waters.

In addition to limiting the amount of pesticides, herbicides, and chemical fertilizers you use in your yard, gardeners can help reduce the amount of runoff that ends up in local waters by developing a rain garden. A well-designed rain garden incorporates bowl-shaped areas planted with water-tolerant native plants, which capture and absorb stormwater runoff from impervious surfaces such as your roof, patio, or driveway.[8] Rain gardens can also provide water sources for backyard wildlife and will help recharge groundwater, buffering regional water supplies when dry conditions return. To find out how to design a rain garden in your yard, visit *http://www.raingardennetwork.com*.

In addition, you can enhance your landscape's ability to absorb stormwater by using pebbles and individual pavers instead of concrete for your driveway or patio.

7. Compost kitchen and garden waste.

Each year, people send millions of tons of kitchen and yard waste into our landfills, where it gets packed down and decomposes without oxygen—a process that spews methane (a highly potent greenhouse gas) into the atmosphere. In addition, it takes a considerable amount of energy just to transport this waste to the landfill in trucks, which means that much more global warming pollution in the form of CO_2.

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Instead of throwing it away, you can easily compost much of this waste in your backyard. In a well-maintained compost pile that is regularly mixed, the added aeration helps eliminate methane production and contributes to healthier decomposition. Ultimately, compost provides an excellent source of nutrients for your garden and can reduce the need to use chemical fertilizers that pollute local water supplies.

Some composting tips:[9]

- Use both "green" material such as grass clippings and fruit and vegetable scraps to add nitrogen and "brown" material such as dead leaves and black-and-white newspaper to add carbon.
- Add a handful of garden soil to inoculate your pile with microorganisms that break down materials and create compost.

- Do not let the pile dry out. Keep it evenly moist but not wet.
- Turn the pile with a pitchfork to aerate it. Turning also speeds up the composting process.
- Compost is ready to be used in the garden when it is black and crumbly.

8. Establish a "greenroof" and plant trees to protect your home from the elements.

A new strategy that is gaining popularity across the country is planting "greenroofs." A greenroof is different from a rooftop garden—it uses special soil and vegetation instead of shingles or tiles as roofing material, which can provide a number of ecological and economic benefits. In particular, a well-designed greenroof can absorb substantial amounts of rainfall and significantly reduce stormwater runoff. A greenroof can also help keep your home or apartment building cooler in summer and warmer in winter, reducing energy costs. And in urban areas, greenroofs can also help reduce what is known as the urban "heat island" effect, which exacerbates the impact of global warming. To learn more, visit *www.greenroofs.com* and *www.greenroofresearch.org*.

Similarly, planting trees near your home to provide shade in summer and shelter the house from cold winter winds can significantly reduce energy use for air conditioning and heating. For example, one study shows that shade trees can reduce energy use for air conditioning by up to 70 percent.[10] And if all of the households in the Northern Plains states of North Dakota, South Dakota, Nebraska, Wyoming, and Montana planted windbreaks of evergreen trees, they could prevent 2 million tons of CO_2 from being emitted every year.[11]

9. Plant lots of trees to absorb and store carbon dioxide.

As all gardeners know, growing plants absorb CO_2 from the atmosphere and store it as carbon in their leaves, branches, and roots (a process called "carbon sequestration"). As it grows, one shade tree can absorb about 50 pounds of CO_2 per year. If every one of America's 91 million gardening households planted just one young shade tree in their backyard or community, those trees would absorb around 2.25 million tons of CO_2 each year. And over their lifetimes (e.g., 40 years), those trees will have removed nearly 100 million tons of CO_2 from the atmosphere.

Taking Action in Your Community

1. Connect places for wildlife by certifying your neighborhood as a Community Wildlife Habitat ™.

The National Wildlife Federation's Certified Wildlife Habitat™ program can help people save a place for birds, butterflies, and other wildlife right in our own yards and gardens. On a larger scale, planting native species and providing the important habitat basics such as food, water, cover, and places for wildlife to bear and raise their young can help maintain or reconnect fragmented habitats and help wildlife cope

JERRY PAVIA

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with global warming. By certifying your own garden and encouraging your neighbors to do the same, you can turn your neighborhood into a Community Wildlife Habitat™.

The National Wildlife Federation has already certified more than 20 communities across the country, uniting backyards, schoolyards, businesses, churchyards, and neighborhood open space for wildlife. To learn more about community certification, visit *http://www.nwf.org/community/*.

2. Participate in citizen science.

Another way for people to get involved is to participate in one or more "citizen science" programs across the country to help provide valuable scientific data to researchers while at the same time gaining an opportunity to get closer to nature.[12] There are a number of networks devoted to following phenological events across North America:

- USA National Phenology Network, *www.uwm.edu/Dept/Geography/npn/index.html*
- Alberta Plantwatch Program, *http://plantwatch.sunsite.ualberta.ca/*
- FrogwatchUSA, *http://www.nwf.org/frogwatchUSA*
- North American Hummingbird Migration Tracking, *http://www.hummingbirds.net/map.html*
- NatureWatch Canada, *http://www.naturewatch.ca/english/*
- PlantWatch North Program, *http://www.emannorth.ca/plantwatch/main.cfm*
- Operation RubyThroat, *http://www.rubythroat.org*

3. Encourage local home and garden retailers to carry energy-efficient products.

Home and garden stores across America are starting to carry a variety of energy-efficient products. A good way to identify some of the most efficient products, from lighting and appliances to windows and doors, is to look for the Energy Star® label. If you can't find what you want at your local store, let the salespeople or customer service representatives know that offering energy-efficient products is important to you.

The same goes for your local garden centers. Although the number of horticulture and landscaping industries that offer native plants for sale is increasing, it can still be challenging to find them at your local nursery. Furthermore, when native plants are available, they are often cultivated varieties or hybrids that have been developed for certain ornamental qualities, as opposed to their wildlife value.[13] Nevertheless, these plants are still likely to be better options than many exotics. And if more and more people ask their local nurseries to offer a greater variety of wild native plants, these will become increasingly available.

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Actions for Your Elected Officials

You can play an important role in moving America toward a cleaner, safer, and more sustainable energy future by contacting your elected officials by calling, e-mailing, writing letters or, when possible, visiting them in person and urging them to implement a strong plan of action to combat global warming.

JERRY PAVIA

To find out how to reach your elected officials at the local, state, and federal levels, visit *http://www.usa.gov/Contact/Elected.shtml*.

There are a number of meaningful actions for your government to take:

Federal actions:

Some of the most important steps that we can take to fully transform the energy investments being made across the country and reduce the nation's global warming pollution are strategies that our federal government must enact. You should urge your senators and representatives in Congress to:

- Place mandatory limits on the nation's global warming pollution.
- Raise fuel economy standards for cars and sport-utility vehicles.
- Make bold investments in clean and efficient energy technologies and phase out coal and oil subsidies.
- Enact new standards for renewable power.

State actions:

There are also a number of meaningful actions that states can take, and in some cases are already taking, to address global warming. Many states actually contribute more global warming pollution than entire countries in other parts of the world. For example, the amount of greenhouse gases emitted by Washington, Oregon, California, and Nevada combined equals that of the United Kingdom. And if states were ranked individually, six states—Texas, California, Pennsylvania, Ohio, Illinois, and Florida—would rank among the top 30 emitters internationally.[14]

State governments can make a significant dent in the nation's overall pollution by implementing a number of actions within their jurisdiction. You should urge your governor and state legislators to:

- Require utilities to generate a share of their electricity from renewable energy sources such as the sun and wind.
- Collect revenue from electric utility customers to fund sustainable energy programs.
- Allow customers with electric generating systems (such as rooftop solar photovoltaic panels) to sell unused electricity back to their local utility.
- Require stricter vehicle emissions standards and promote cleaner, advanced-technology vehicles.

U.S. DEPARTMENT OF AGRICULTURE

Local actions:

At the local level, hundreds of cities across the country have made a commitment to reducing their greenhouse gas emissions by endorsing the U.S. Mayors Climate Protection Agreement, an initiative begun in 2005 to engage cities in solutions to global warming. Cities participating in the program have agreed to implement programs to reduce global warming pollution in their own jurisdictions through community-based activities. You should encourage your city officials to:

- Develop programs to curb suburban sprawl, including creating incentives to increase public transit use, promoting bicycle- and pedestrian-friendly options, and linking transportation funding to effective growth-management strategies.
- Expand parks and "green space" and plant more trees in urban areas, which can help minimize the urban heat island effect as well as absorb and store CO_2.
- Improve the energy efficiency of government buildings by installing energy-efficient lighting, heating and cooling units, and programmable thermostats.
- Reduce the energy used in city motor vehicle fleets by replacing old vehicles with gas/electric hybrids or vehicles that run on less polluting alternative fuels such as biodiesel.
- Expand recycling programs to include a range of materials, including mixed paper, cardboard, plastics, glass, and metal.

To learn more about the mayors' initiative, visit *http://www.seattle.gov/mayor/climate*.

WING-CHI POON

SINCE THE START OF THE INDUSTRIAL REVOLUTION, THE AMOUNT OF CARBON POLLUTION IN THE ATMOSPHERE HAS RISEN TO A LEVEL GREATER THAN ANY OTHER TIME IN AT LEAST THE PAST 650,000 YEARS, AND PERHAPS AS LONG AS 20 MILLION YEARS. AS A RESULT, IN THE TWENTIETH CENTURY ALONE, THE EARTH'S AVERAGE TEMPERATURE HAS RISEN MORE THAN 1.3 DEGREES FAHRENHEIT.

WHY SHOULD YOU CARE?

The Threat of Global Warming

The burning of carbon-based fossil fuels such as coal, oil, and gas in our power plants, factories, homes, and motor vehicles is the driving force behind global warming. Scientific studies show a direct relationship between the amount of CO_2 and other heat-trapping gases being released into the atmosphere due to human activities and the increase in the earth's average surface temperature—the more CO_2 that is emitted, the more the planet warms.

In February 2007, the Intergovernmental Panel on Climate Change (IPCC) released its fourth assessment since 1990 of the large and growing body of science concerning global warming. According to the report, the IPCC has found global warming to be "unequivocal" and "*very likely* due to the observed increase in anthropogenic greenhouse gas concentrations" [emphasis in the original]. [15] Since the start of the Industrial Revolution, the amount of carbon pollution in the atmosphere has risen to a level greater than any other time in at least the past 650,000 years, and perhaps as long as 20 million years.[16] As a result, in the twentieth century alone, the earth's average temperature has risen more than 1.3 degrees Fahrenheit.[17]

This temperature change may not seem like much, but as any gardener knows, just the 1-degree difference from 32 to 33 degrees Fahrenheit over a period of time can determine whether your garden will face a pest-killing freeze or just a cold snap.

On average, eleven of the past twelve years (1995–2006) rank among the twelve warmest years on record since 1850, and the increase in average temperature is expected to accelerate in the coming decades. The IPCC projects that the earth's average temperature will rise by another 4–11 degrees Fahrenheit before the end of this century if the nation and world continue to depend extensively on fossil fuels to meet our energy needs.[18]

Moreover, global warming means far more than hotter weather. As the atmosphere heats up, it disrupts our planet's entire climate system. Average water temperatures are becoming warmer, precipitation patterns are changing, and extreme weather events such as droughts, floods, storms, and heat waves are becoming more frequent and severe. The United States has already experienced the following climate effects associated with global warming:

- Higher average temperatures, particularly in winter months.[19]

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- An increase in average annual precipitation, with an increasing share of precipitation (both rain and snow) falling in intense bursts.[20]
- A considerable lengthening of the frost-free season and earlier date of last-spring freeze.[21]
- More extreme heat waves.[22]
- More extensive drought and wildfires, particularly in the West.[23]
- Earlier spring snowmelt and significant decline in average snowpack in the Rocky Mountains, Cascades, and Sierra Nevada ranges.[24]
- An increase in the intensity, duration, and destructiveness of hurricanes.[25]

Unless global warming is abated, these trends will continue to worsen in the coming years and decades. For example, scientists project major changes in the character of precipitation across the United States, with a significant increase in the intensity of precipitation events and either increases or decreases in their duration and frequency, depending on the region.[26] Recent studies also show a significant trend toward stronger, more frequent, and longer lasting heat waves across most of the country before the end of this century. It may seem counterintuitive, but these changes will lead to more flooding as well as to more droughts. Higher temperatures contribute to increased evaporation, which decreases moisture levels in soils. At the same time, greater evaporation puts more moisture into the atmosphere to build up as rain.

In many western states, global warming is expected to contribute to a considerable reduction in average snowpack and earlier, more rapid spring snowmelt, which will lead to more wintertime flooding and decreased summertime water supply in major river basins *(see Table 3)*. Winter snowpack accounts for 75 percent of the West's water supply and is the primary source of water in many areas in dry summer months as the snow melts from high-elevation mountains; therefore, these changes would place considerable strain on water resources throughout the region.

The trend toward fewer frost days or growing-season days is expected to continue as well, although the greatest relative changes will occur in the West due to changes in regional atmospheric circulation.[30] The western half of the country will see warmer air circulating from the south, leading to warmer average nighttime temperatures, which is the most important determinant of frost events. On the other hand, the East will see more air coming down from the north, so nighttime temperatures will not rise as much.

In addition to affecting the climate, global warming is causing sea levels around the world to rise at an unprecedented rate due to a combination of thermal expansion of the oceans and rapidly melting glaciers and polar ice caps. The average sea level is expected to rise 7–23 inches before the end of this century, and perhaps as much as 31 inches over that time if the rate of ice melt from Greenland and Antarctica increases as some models predict.[31] Along coasts with gradually sloped shores, such as Florida, the Gulf Coast, and the Mid-Atlantic region, a 31-inch sea level rise would translate to a horizontal advance of water inland of as

TABLE 3.

Projected changes in average snowpack in the West due to global warming[29]

(compared to the average conditions for the period 1961-1990)

	Period	
Region	2025-2034	2090-2099
Pacific Northwest	-44%	-88%
Central Rocky Mountains	-27%	-75%
Sierra Nevada	-74%	-100%
Southern Rocky Mountains	-51%	-98%

SOURCE: Data from G. J. McCabe and D. M. Wolock, "General-Circulation-Model Simulations of Future Snowpack in the Western United States" (Denver, CO: U.S. Geological Survey, 1999), *http://smig.usgs.gov/SMIG/features_0300/snowpack_gcm.html* (accessed February 28, 2007).

TABLE 4. Regional climate change trends for the United States		
REGION	20TH CENTURY TRENDS	PROJECTED CHANGES
Alaska	Substantial increase in average temperatures of 4–7°F. Growing season has lengthened by 14 days since the 1950s. 30% increase in precipitation between 1968 and 1990.	Rapid Arctic warming will continue, from 5–12°F to 7–18°F by 2100. Strongest warming to the north and in winter. 20–25% increase in precipitation in north and northwest, 10% decrease in south. Increased evaporation due to higher temperatures likely to offset increases in precipitation, leading to drier soils across the state.
Pacific Northwest (WA, OR, ID, western MT)	Increase in average temperature of 1–3°F. Average increase of 10% in annual precipitation, with increases reaching 30–40% in eastern WA and northern ID. Declines in average snowpack, earlier spring snowmelt.	Significant increase in average temperatures, with 3°F by 2030s and 5°F by 2050s. By 2090s, average summer temperatures will rise by 7–8°F, winter temperatures by 8–11°F. Average increase in precipitation, particularly in winter, with more falling as rain than as snow. Significant decline in snowpack. Decline in summer soil moisture, particularly in northern region.
West (CA, NV, UT, AZ, western NM, western CO)	Average temperatures have increased 2–5°F. General increases in precipitation, although increase in drought in AZ and Central Rockies. Length of snow season decreased by 16 days from 1951 to 1996 in CA and NV. Extreme precipitation events have increased.	Significant increase in temperatures, from 5°F in CA to 8–11°F in CO, NM, and UT. Substantial increase in rainfall, especially in CA, NV, and AZ. Higher temperatures will lead to increased evaporation and drought in some areas, and a significant decline in snowpack in the Rocky Mountains and Sierra Nevada likely to reduce summer water supply.
Great Plains (ND, SD, WY, NE, OK, KS, eastern MT, eastern CO, eastern NM, most of TX)	Temperatures have risen more than 2°F across the northern and central Great Plains, with increases up to 5.5°F in parts of MT, ND, and SD. Annual precipitation has decreased by more than 10% in eastern MT, ND, eastern WY, and CO. In the eastern portion of the region, average precipitation has increased more than 10%. TX has experience significantly more high-intensity rainfall. Snow season ends earlier in spring.	5–12°F increase in average temperatures, particularly in the western parts of the Plains. Greater number of extreme heat events (3 days in a row above 90°F). More warming in winter and spring than in summer and fall. Average precipitation projected to decrease in southern Plains, increase in north. Evaporation due to higher temperatures expected to surpass any increases in precipitation, leading to reduced net soil moisture, drought for much of the area.
Midwest (MN, WI, MI, IA, MO, IL, IN, OH)	Northern portion of the Midwest has warmed by almost 4°F, while southern portion along Ohio River valley has cooled about 1°F. Increase in annual precipitation by as much as 10–20%, including significant increase in number of days with heavy precipitation events.	Temperatures will increase throughout the Midwest, particularly in the northern region, which could see average temperatures rise by 5–10°F by 2100. Average minimum temperature likely to increase 1–2°F more than the maximum. Precipitation also likely to continue upward trend, but increased temperatures will lead to increased evaporation and more drought-like conditions across much of the region.

TABLE 4. Regional climate change trends for the United States *(continued)*

REGION	20TH CENTURY TRENDS	PROJECTED CHANGES
Southeast (AR, eastern TX, LA, KY, TN, MS, AL, GA, FL, NC, SC, VA)	Up to 4°F increase in average temperatures along coastal region over the past century, with some inland cooling (but general overall temperature increase since the 1970s). Strong (20–30%) increase in annual rainfall over past 100 years across MS, AR, SC, TN, AL, and LA. 10% increase in percentage of Southeast landscape experiencing severe wetness.	Warming across the region (although models vary on rate). Increase in July heat index from 8–15°F to perhaps more than 20°F for much of the region. Higher average temperatures are projected to reduce soil moisture due to increase in evaporation. Significant increase (20%) in precipitation, but more extremes such as flooding and droughts.
Northeast (MD, WV, RI, DE, PA, CT, NY, MA, VT, NH, ME)	Temperature increases of up to 4°F along coastal margins from Chesapeake Bay through ME. 20% increase in average precipitation over much of the region. Greater precipitation extremes. Period between first and last dates with snow on the ground has decreased 7 days over past 50 years.	4–5°F increase in winter minimum temperatures by 2100, particularly in coastal regions. Up to 25% increase in average precipitation. A decrease in winter snowfalls and periods of extreme cold and an increase in heavy rainfall events. An increase in the summer heat index from 3–5°F to as much as 8–10°F.
Islands (HI, Pacific, Caribbean)	Average annual temperatures in the Caribbean islands have increased more than 1°F. Average annual temperatures in the Pacific Islands have increased by about 0.5°F. Globally, sea level has risen by 4–8 inches, with significant local variation. Intensity of tropical storms in both the Atlantic and Pacific has increased significantly.	Significant increase in sea levels, storm intensity will likely have greatest impact. Also likelihood of greater climate extremes, including droughts and flooding events.

SOURCE: National Assessment Synthesis Team, Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change (Washington, DC: U.S. Global Change Research Program, 2000).

much as 516 feet. Even at the low range of these projections, sea level rise will inundate property, destroy vital habitats, and make our coasts more vulnerable to storm surges and erosion.

Table 4 provides a summary of the recent and projected changes in regional climate conditions across the country due to global warming. It is important to note that, for all of these trends, the more global warming pollution we allow to build up in our atmosphere, the more likely the occurrence of worst-case scenarios.

Gardens Are Our Windows to Nature

Gardeners and backyard wildlife enthusiasts know as well as anyone that the life cycles and behavior of plants and animals are closely linked with the changing seasons. We know spring is near when our crocuses and daffodils begin to emerge. We wait until after the last frost to plant our tender annuals. And we are among the first people to notice when migratory songbirds first arrive in the spring and depart in the fall.

The study of the annual timing of these and other climate-sensitive natural events is known as "phenology," and recent shifts in the phenology of many plants and animals are being found in parks, botanical gardens, and backyards all across the country.[32] In fact,

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scientists are finding on a broad scale what many gardeners have already been noticing, such as earlier leaf out and bloom times, a longer growing season, earlier emergence of butterflies and other insects, and the arrival of "new" birds at the backyard feeder *(see Box 1 on page 24)*.

But this is a double-edged sword. The changes in phenology and distribution of plants and animals not only provide a strong signal that global warming is happening. They are also warning signs that global warming is already having a profound impact on nature and threatens to fundamentally alter the ecosystems that sustain life as we know it.

More Hassles for Gardeners, a Catastrophe for Nature

Numerous studies suggest that global warming will make gardening increasingly challenging as we deal with its impacts. Heavier downpours and more intense storms will lead to extensive flooding in vulnerable areas, causing costly damage to homes and businesses. When flooding and seawater intrusion from Hurricane Katrina in 2005 destroyed the vast majority of the New Orleans Botanical Garden's collection—not to mention displaced thousands of people—we saw just how devastating such events can be. Heavy rainfall is also expected to contribute to serious water quality problems across the country. Instead of soaking into the ground, water from heavy rains tends to rapidly run off into storm drains, carrying with it pesticides, herbicides, fertilizers, and other pollutants. This stormwater runoff is one of the greatest sources of water pollution in our lakes, streams, and coastal waters.

At the other extreme, ongoing drought conditions and declining snowpack in many regions will cause a significant decline in water resources. The severe drought conditions plaguing parts of the nation over the past few years have already led to major watering restrictions and left withered lawns and gardens in their wake. With global warming, lack of sufficient water for gardens, agriculture, and urban consumption, not to mention wildlife, will become even more problematic.

In addition, droughts and heat waves often encourage some of the most damaging garden pests such as aphids, spider mites, locusts, and whiteflies.[49]

BOX 1. Gardens and Backyard Wildlife—Sentinels of a Changing Climate

Plants Leafing Out and Blooming Earlier

- Widespread evidence indicates that earlier spring warm temperatures are causing both Chinese lilac *(Syringa x chinensis)* and honeysuckles *(Lonicera tatarica and Lonicera korolkowii)* to leaf out and bloom 5–6 days earlier than they did in the 1950s.[33]
- In Wisconsin, a comparison of 1980s–1990s data with that gathered by Aldo Leopold in the 1930s–1940s shows a dramatic advancement of spring events—forest phlox *(Phlox divaricata)* blooms 15 days earlier, butterfly weed *(Asclepias tuberosa)* blooms 18 days earlier, and red columbine *(Aquilegia canadensis)* blooms 13 days earlier.[34]
- Flowering plants at Boston's Arnold Arboretum are blooming more than a week earlier on average than they did more than a century ago, corresponding with a 3-degree Fahrenheit increase in average temperatures.[35]
- Scientists at the Smithsonian Institution have discovered the famous cherry blossoms *(Prunus serrulata and Prunus x edoensis)* in Washington, D.C., are peaking an average of 7 days earlier than they did 30 years ago, a trend they associate with an increase in the region's average minimum temperature.[36]
- Satellite images over the period 1981–1999 show that the growing season over much of the Northern Hemisphere has lengthened by about 12 days.[37]

Birds and Butterflies Breeding/Migrating Earlier

- The breeding season of the Mexican jay *(Aphelocoma ultramarina)* in the Chiricahua Mountains of southern Arizona advanced by average of 10 days between 1971 and 1998, corresponding with a 4.5-degree Fahrenheit increase in April monthly minimum temperatures—an important factor influencing the laying date of first clutches.[38]
- Across the United States and Canada, the tree swallow *(Tachycineta bicolor)* has been laying its eggs an average of 9 days earlier as May temperatures have risen.[39]
- In Wisconsin, the northern cardinal *(Cardinalis cardinalis)* is singing 22 days earlier, the Canada goose (Branta canadensis) is arriving 29 days earlier, and the American robin *(Turdus migratorius)* is arriving 10 days earlier than in the 1930s–1940s.[40]
- Research of migratory birds in North America shows that the arrival dates of 20 species were up to 21 days earlier in 1994 than in 1965, while just a few species were later.[41]
- A central California study has found that 70 percent of 23 butterfly species in the region have advanced first flight date by 24 days over 31 years, driven by warmer, drier winters.[42]

In addition to affecting plant and animal phenology, climatic variables such as temperature and precipitation can play a major role in determining the places in which many plants and animals can thrive, both in nature and in the garden.

Species on the Move

- The Edith's checkerspot butterfly *(Euphydryas editha)* in western North America has demonstrated a clear range shift northward and upward in elevation in response to a 1.3-degree Fahrenheit increase in average temperatures.[43]
- Also in the West, the range of sachem skipper butterfly *(Atalopedes campestris)* has expanded 420 miles from California to Washington in 35 years. It can now be found in areas that had previously been too cold for it to survive.[44]
- The rufous hummingbird *(Selasphorus rufus)* has undergone a major shift in its winter range since the early 1990s. Once wintering primarily in Mexico, this bird is increasingly being seen in Gulf Coast states, where average winter temperatures have risen about 2 degrees Fahrenheit over the past 30 years.[45]
- Five species of tropical dragonfly have apparently naturally moved north into Florida from Cuba and the Bahamas following changes in regional temperatures.[46]
- The piñon jay *(Gymnorhinus cyanocephalus)* has been showing up in greater numbers in lowland backyard feeders as extensive drought and associated wildfires in Utah and Wyoming have wiped out the piñon pine *(Pinus edulis)* forests on which it depends.[47]
- Increased rainfall and shifts in plant types from succulent and herbaceous plants to woody plants have enabled a number of bird species to expand into areas of the Great Basin (including parts of Arizona, Nevada, Utah, and western Colorado).[48]

According to one study, a 5.5-degree Fahrenheit increase in temperature could mean the difference between aphids that produce 300,000 offspring versus those that produce more than 1 million offspring over a 2-month period.[50] Similarly, drought-stricken plants are more susceptible to diseases, including aspergillus *(Aspergillus flavus)* and powdery mildew.[51]

Garden weeds such as dandelion *(Taraxacum officinale)* and lambsquarters *(Chenopodium album)* are expected to benefit from global warming as well, making the chore of weeding even more tedious.[52] And those who suffer from allergies may also be disappointed that global warming will exacerbate hay fever by increasing ragweed *(Ambrosia artemisiifolia)* pollen production and make poison ivy *(Toxicodendron radicans)* more toxic to people.[53]

The bottom line: if global warming is left unchecked, gardeners can expect many more of these annoying, costly, and time-consuming problems in the future. More importantly, however, is that what may be bad for gardens will be much worse for nature, from the expansion of invasive nonnative species to the disruption of ecosystems and the extinction of thousands of species.

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Expansion of Harmful Invasive Species, Pests, and Diseases

While weeds and pests in the garden can be frustrating and time consuming to control, in nature invasive species can wreak absolute havoc. By definition, an "invasive" species is a nonnative plant, animal, or other organism that, once introduced into a new environment, outcompetes native species for habitat and food. Although not all exotic species are invasive, those that are can cause tremendous problems.

The introduction of invasive nonnative species into our environment has been one of the most serious and devastating threats to our native wildlife. According to the U.S. Fish & Wildlife Service, harmful invasive species are believed to have contributed to the listing of at least 160 native species as threatened or endangered under the Endangered Species Act.[54]

Particularly troubling is the fact that a number of nonnative plants that people have brought into their gardens as ornamentals, including purple loosestrife *(Lythrum salicaria),* Japanese honeysuckle *(Lonicera japonica)*, and English ivy *(Hedera helix),* have turned out to be some of the most highly invasive and damaging species when introduced into natural habitats. With global warming, these and other invasive species across the country are expected to gain even more of a foothold.[55] Scientists estimate that global warming will enable 48 percent of the invasive plants and animals currently established in the United States to expand their distributions northward as climatic variables change in their favor.[56]

In many places, factors such as cold winter temperatures or moisture conditions have prevented

a number of invasive species from thriving, but increasing temperatures and shifts in precipitation patterns due to global warming may enable some of these species to move into new areas. Today, the invasive species kudzu *(Pueraria montana var. lobata)* and garlic mustard *(Alliaria petiolata)* are able to survive in areas much farther north than in the past as winter temperatures have warmed.

Studies also show that several of North America's most noxious weeds, including Canada thistle *(Cirsium arvense)*, spotted knapweed *(Centaurea stoebe ssp. micranthos)*, and leafy spurge *(Euphorbia esula)*, are more likely to benefit from changes in atmospheric gas concentrations than are native plants, thereby giving them another competitive advantage.[57]

Many exotic pest insects are also likely to benefit from global warming. An important indicator of an earlier growing season in Ohio, for example, has been the emergence timing of the black vine weevil *(Otiorhynchus sulcatus)*, a highly damaging nursery pest. Adults have been emerging 3 weeks earlier, on average, than they did in the 1970s, corresponding with the blooming of black locust *(Robinia pseudoacacia)*.[58] Gypsy moth *(Lymantria dispar)* infestations are also on the rise in Utah and other parts of the western United States, where the climate is becoming more suitable for this devastating species.[59] In addition, the range of the meadow spittlebug *(Philaenus spumarius)*, a serious crop pest, has moved northward along the California coast since 1988, corresponding with shifts in humidity and temperatures due to global warming.[60]

Even some native plants and animals can become problematic if the ecosystems in which they exist become disrupted. For example, warmer average temperatures in the Rocky Mountain region have enabled the mountain pine beetle *(Dendroctonus ponderosae)* to speed up its life cycle. In higher-elevation

BOX 2. Zoning Out: Global Warming Warrants New Garden Maps

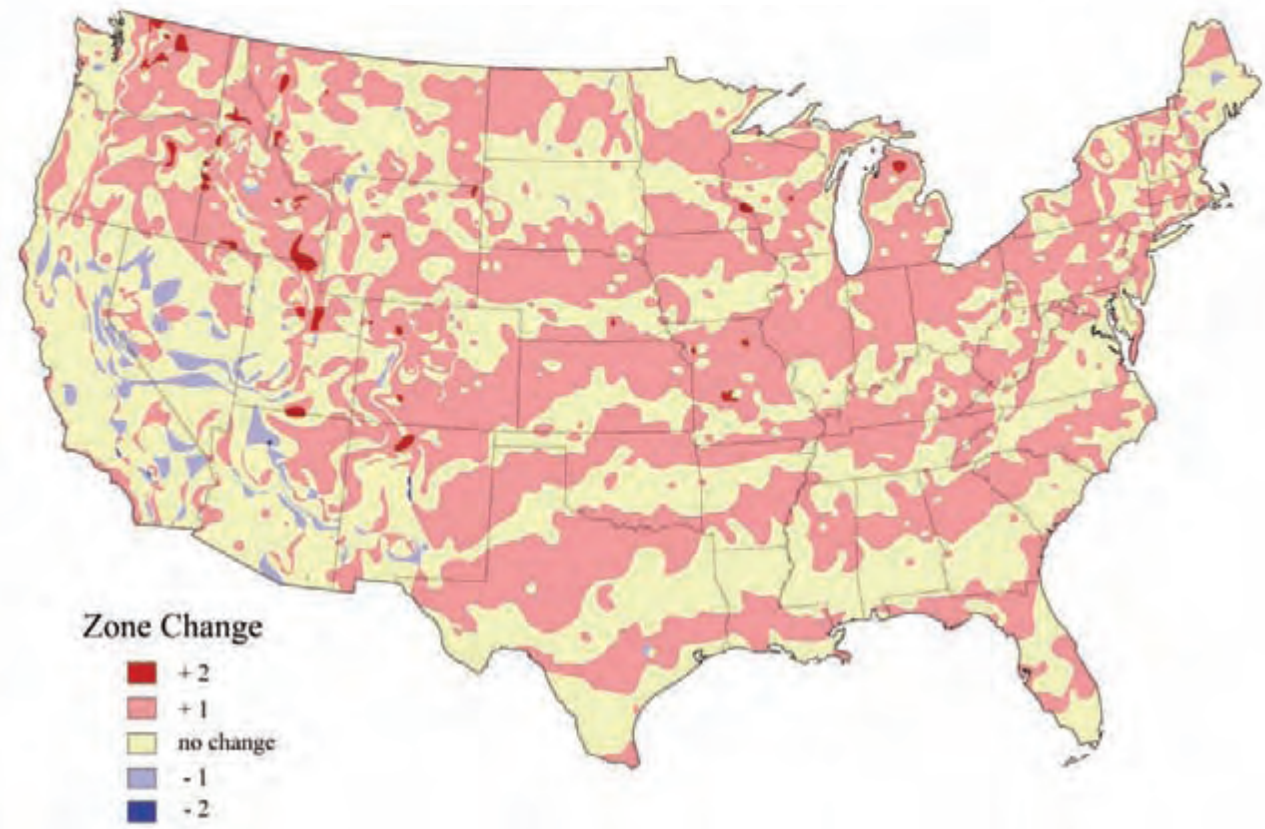
There are many factors that ultimately determine the success of plants both in nature and in the garden, from soil quality and rainfall patterns to temperatures and the amount of sunshine the garden receives. In nature, differences in all of these variables have helped determine the location and diversity of native vegetation and the ecosystems they support. They have also been factors in determining where nonnative plants may thrive. In the garden, it is possible to manage many of these factors to a certain extent—but unless you have a greenhouse, temperature is likely to be an important determinant of what you can successfully grow in your area.

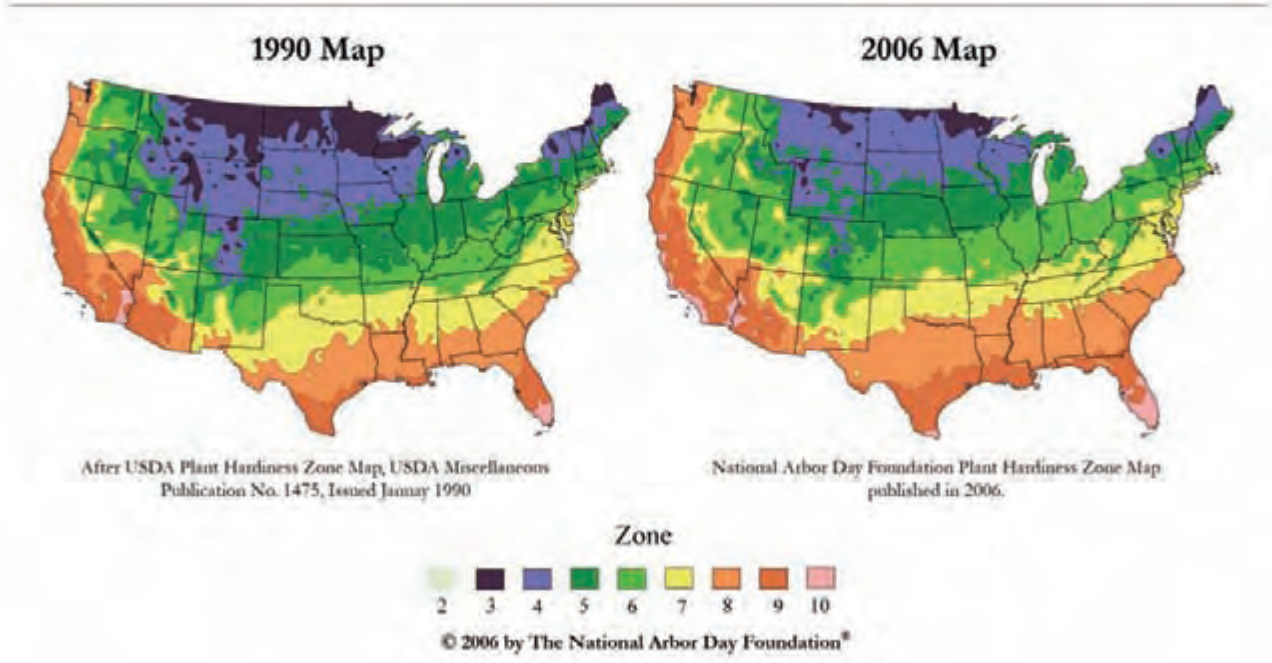
Average low and high temperatures, as well as the maximum lows and highs, can have a significant influence on plants. For example, some plants cannot tolerate cold temperatures and will not survive major frost or freeze events. Still others, such as many fruit trees, may need periodic cold events to enable fruit to form. And as some plants thrive in hot weather, others will wilt and die when temperatures soar.

Many gardeners have come to rely on one or more "zone maps" as a guide to identify which plants to choose for their gardens (e.g., USDA Plant Hardiness map, USDA Last Spring Frost Map, USDA First Autumn Frost Map, Sunset's Garden Climate Zones Map, and the American Horticultural Society's Plant Heat-Zone Map). One of the most commonly referenced versions is the USDA Plant Hardiness map, which determines various planting zones across the country based on minimum winter temperatures for the particular region. Although the map is not considered to be an accurate guide for the western United States, it has generally been useful for the East. As regional temperatures have changed due to global warming, however, so too have the zones. Accordingly, the National Arbor Day Foundation has revised the USDA map significantly to reflect the recent trends.

Eventually, the same will need to be done for all of the various planting zone maps that depend on climatic variables to reflect the changes that are underway and will continue if global warming continues unchecked.

Diffferences between 1990 USDA hardiness zones and 2006 arborday.org hardiness zones reflect warmer climate





After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

TABLE 5. State trees and state flowers *(species projected to shift out of their official state are highlighted in bold)*[a]

STATE	OFFICIAL STATE TREE	OFFICIAL STATE FLOWER
Alabama	Longleaf pine *(Pinus palustris)*	Camellia *(Camellia japonica)*
Alaska	Sitka spruce *(Picea sitchensis)*	Forget-me-not (Myosotis asiatica)
Arizona	Palo verde *(genus Parkinsonia)*	Saguaro cactus blossom *(Carnegiea gigantea)*
Arkansas	Pine *(genus Pinus)*	Apple blossom *(Malus pumila)*
California	Coast redwood *(Sequoia sempervirens)* and giant sequoia *(Sequoiadendron giganteum)*	California poppy *(Eschscholzia californica)*
Colorado	Blue spruce *(Picea pungens)*	Rocky Mountain columbine *(Aquilegia caerulea)*
Connecticut	White oak *(Quercus alba)*	**Mountain laurel *(Kalmia latifolia)***
Delaware	**American holly *(Ilex opaca)***	**Peach blossom *(Prunus persica)***
District of Columbia	**Scarlet oak *(Quercus coccinea)***	American Beauty rose *(Rosa 'American Beauty')*
Florida	Cabbage palmetto *(Sabal palmetto)*	Orange blossom *(Citrus ¥sinensis)*
Georgia	**Live oak *(Quercus virginiana)***	Cherokee rose *(Rosa laevigata)*
Hawaii	Candlenut tree, kukui *(Aleurites moluccana)*	Pua aloalo *(Hibiscus brackenridgei)*
Idaho	Western white pine *(Pinus monticola)*	**Syringa mock orange *(Philadelphus lewisii)***
Illinois	**White oak *(Quercus alba)***	**Purple violet *(genus Viola)***
Indiana	**Tulip poplar *(Liriodendron tulipifera)***	Peony *(Paeonia lactiflora)*
Iowa	Oak *(genus Quercus)*	Wild prairie rose *(Rosa arkansana)*
Kansas	**Eastern cottonwood *(Populus deltoides)***	**Sunflower *(Helianthus annuus)***
Kentucky	**Tulip poplar *(Liriodendron tulipifera)***	Goldenrod *(Solidago canadensis var. scabra)*
Louisiana	**Bald cypress *(Taxodium distichum)***	**Southern magnolia *(Magnolia grandiflora)***
Maine	Eastern white pine *(Pinus strobus)*	Eastern white pine tassel and cone *(Pinus strobus)*
Maryland	White oak *(Quercus alba)*	**Black-eyed Susan *(Rudbeckia hirta)***
Massachusetts	American elm *(Ulmus americana)*	**Mayflower *(Epigaea repens)***
Michigan	Eastern white pine *(Pinus strobus)*	Apple blossom *(Malus pumila)*
Minnesota	Red pine *(Pinus resinosa)*	**Pink and white ladyslipper *(Cypripedium reginae)***
Mississippi	**Magnolia *(genus Magnolia)***	**Magnolia *(genus Magnolia)***
Missouri	Flowering dogwood *(Cornus florida)*	Hawthorn *(genus Crataegus)*
Montana	Ponderosa pine *(Pinus ponderosa)*	Bitterroot *(Lewisia rediviva)*

TABLE 5. State trees and state flowers *(continued) (species projected to shift out of their official state are highlighted in bold)*[a]

STATE	OFFICIAL STATE TREE	OFFICIAL STATE FLOWER
Nebraska	**Eastern cottonwood *(Populus deltoides)***	**Goldenrod *(Solidago gigantea)***
Nevada	Singleleaf piñon pine *(Pinus monophylla)* and bristlecone pine *(Pinus longaeva)*	**Sagebrush *(Artemisia tridentata)***
New Hampshire	Paper birch *(Betula papyrifera)*	Purple lilac *(Syringa vulgaris)*
New Jersey	Northern red oak *(Quercus rubra)*	**Violet *(Viola sororia)***
New Mexico	Piñon pine *(Pinus edulis)*	Yucca *(Yucca glauca)*
New York	Sugar maple *(Acer saccharum)*	Rose *(genus Rosa)*
North Carolina	Longleaf pine *(Pinus palustris)*	**Flowering dogwood *(Cornus florida)***
North Dakota	American elm *(Ulmus americana)*	Wild prairie rose *(Rosa arkansana)*
Ohio	**Ohio buckeye *(Aesculus glabra)***	Scarlet carnation *(Dianthus caryophyllus)*
Oklahoma	**Eastern redbud *(Cercis canadensis)***	Mistletoe *(Phoradendron leucarpum)*
Oregon	Douglas-fir *(Pseudotsuga menziesii)*	**Oregon grape *(Mahonia aquifolium)***
Pennsylvania	**Eastern hemlock *(Tsuga canadensis)***	**Mountain laurel *(Kalmia latifolia)***
Rhode Island	Red maple *(Acer rubrum)*	Violet *(Viola palmata)*
South Carolina	Cabbage palmetto *(Sabal palmetto)*	Yellow jessamine *(Gelsemium sempervirens)*
South Dakota	**Black Hills spruce *(Picea glauca var. densata)***	Pasque flower *(Anemone patens var. multifida)*
Tennessee	**Tulip poplar *(Liriodendron tulipifera)***	Iris *(Iris germanica)*
Texas	**Pecan *(Carya illinoinensis)***	Texas bluebonnet *(genus Lupinus)*
Utah	**Blue spruce *(Picea pungens)***	Sego lily *(genus Calochortus)*
Vermont	Sugar maple *(Acer saccharum)*	Red clover *(Trifolium pratense)*
Virginia	**Flowering dogwood *(Cornus florida)***	**Flowering dogwood *(Cornus florida)***
Washington	Western hemlock *(Tsuga heterophylla)*	**Coast rhododendron *(Rhododendron macrophyllum)***
West Virginia	Sugar maple *(Acer saccharum)*	Rhododendron *(Rhododendron maximum)*
Wisconsin	Sugar maple *(Acer saccharum)*	Violet *(Viola sororia)*
Wyoming	**Plains cottonwood *(Populus deltoides subsp. monilifera)***	Indian paintbrush *(Castilleja linariifolia)*
Puerto Rico	Silk-cotton tree *(Ceiba pentandra)*	Puerto Rico hibiscus *(Thespesia grandiflora)*
U.S. Virgin Islands	No official tree	Yellow trumpetbush *(Tecoma stans)*

SOURCE: The United States National Arboretum, "State Trees & State Flowers," http://www.usna.usda.gov/Gardens/collections/statetreeflower.html (accessed November 20, 2006).

[a] These projections are based on the model runs by Natural Resources Canada under the IPCC A2 scenario using the HADCM3 model, which projects global average temperature increase of more than 6°F by the 2080s.

areas, it now takes just one year per generation, rather than two, which has significantly increased its population abundance and the amount of damage it has caused to forests.[61] And in Ohio, the bagworm *(Thyridopteryx ephemeraeformis)* is now expanding north as winter temperatures have increased, causing new problems for shade trees and woody ornamentals north of I-70.[62]

Threats to Native and Iconic Species: No More Oregon Grape in Oregon?

Even as many opportunistic plants are expected to thrive under global warming, there are a number of important native and non-problematic exotic plants that may ultimately no longer find suitable climate conditions in their historic range.

New research shows that global warming could wipe out one-fifth of wildflower species in parts of the West as dominant grasses take over.[63] Studies also suggest that with a mean global warming of 5.4 degrees Fahrenheit, which is well within the range of warming projected during this century, 7–11 percent of 15,148 native vascular plant species in North America (1,060–1,670 species) could be entirely out of their historically optimal climatic range.[64]

In fact, some of the nation's most beloved plants (both native and exotic) may experience significant declines in the future. For example, scientists at Natural Resources Canada *(see Table 5 on pages 28 and 29)* have developed preliminary range maps based on climatic variables under which a number of plant species for which they have sufficient data currently thrive and how their distribution might look due to changes in temperatures and precipitation from global warming.[65]

Based on these model results, many states may no longer have a favorable climate for their official State Tree or State Flower before this century is out. Imagine Virginia or North Carolina without the flowering dogwood *(Cornus florida)*; Louisiana without bald cypress *(Taxodium distichum)* and southern magnolia *(Magnolia grandiflora)*; Kansas without the sunflower *(Helianthus annuus)*; and Ohio without the Ohio buckeye *(Aesculus glabra)*!

ISTOCK

Disrupted Ecosystems and Species Extinctions

One of the greatest concerns about global warming is what it will mean for entire ecosystems—and for the people and wildlife that depend on them. As diverse species respond to global warming in different ways, important connections between pollinators, breeding birds, insects, and other wildlife and the plants on which they depend will become disrupted. If the relationships among species and their environment decouple, the consequences can ultimately be disastrous.

For example, butterfly caterpillars may hatch before the leaves of their foodplants are present or are otherwise unavailable. In the case of the Edith's checkerspot butterfly *(Euphydryas editha)*, there has been a climate-driven mismatch between caterpillar growth and the timing of its host plants drying up at the end of the season. Observations of this species along its southern-most habitat range have shown that, in many cases, by the time the caterpillar eggs hatched, the plants were already half dry, yielding suboptimal food sources. This has led to high extinction rates among populations at the southern edge of the species' range.

Pollinators such as hummingbirds and bees may arrive either too early or too late to feed on the flowers on which they normally rely, affecting both the pollinators and their host plants. Studies in the Rocky Mountain region show that early flowering species such as larkspur *(Delphinium nuttallianum)*, an important plant for pollinators such as hummingbirds and bumblebee queens, experience lower abundance and fewer seeds in seasons when average snowpack is low and snowmelt occurs too early. If habitat quality for pollinators declines, it may ultimately be detrimental to late-season plants, such as ipomopsis *(Ipomopsis aggregata),* that also depend on pollinators.

Similarly, birds may migrate in spring only to find that the insects, plants, or other foods they eat are not available. Scientists at the Rocky Mountain Biological Laboratory in Colorado, for example, have discovered that the American robin *(Turdus migratorius)* is migrating to the region an average of 2 weeks earlier than it did 23 years ago. They attribute this shift to the likelihood that the birds are responding to warmer temperatures at lower altitudes that typify their wintering grounds.

The problem is that the robins are arriving at their higher-altitude summer breeding grounds only to encounter winter conditions there. There is now a 65-day gap between the date of the first robin sighting and the first date of bare ground at the snow measuring station, 18 days longer than in 1981. As a result, the birds must wait longer for the snow to melt before they can find worms, their preferred food. The added concern is that, even if they were to go back down to lower elevations to wait things out, they may be at risk of running out of food there, as well, if soils quickly dry up (which makes worms move deeper into the ground).

Making matters worse is the fact that, as the landscape becomes increasingly fragmented due to the development of roads, buildings, and farms, the ability of species to move to find more favorable conditions is that much harder. Recent studies suggest that as many as a million species of plants and animals around the world could be threatened with extinction between now and 2050 if global warming continues unchecked.

In the end, the combination of global warming and the many other problems that unsustainable human activities are creating will have truly catastrophic consequences for people and nature alike if we fail to act.

CONCLUSION

Fortunately, each of us can play an important role in combating global warming, restoring and protecting native species and habitats, and ensuring that the plants, animals, and other wonderful things our natural world provides us will endure for our children's future and, in fact, all generations to come. The National Wildlife Federation is dedicated to providing you with information and inspiration to help you make a difference.

SUZANNE DEJOHN

AFTERWORD

SINCE 1973, THE NATIONAL GARDENING ASSOCIATION *(www.garden.org)* has been providing gardeners with information and inspiration to help them garden in an ecologically sound manner, not only because we believe it is best for the environment, but also because we believe environmentally sound practices result in healthier and more beautiful landscapes. We applaud the National Wildlife Federation for producing this important guide that will increase awareness about global warming and inspire gardeners to minimize their contributions to climate change.

There's a perception among some people that doing the right thing for the environment requires sacrifice and extra work, but when it comes to gardening the reverse is often true. For example, replacing large expanses of lawn with low-maintenance native wildflowers reduces the time and expense of mowing, fertilizing, and watering, with the added benefit of beautiful flowers. It's win–win.

Taking steps to conserve and protect water resources, using fertilizers and pesticides judiciously, and choosing low-maintenance plants are all important parts of "ecological" gardening. Minimizing the use of gasoline-powered equipment is also vital. However, another technique, often overlooked, involves using plants for energy conservation.

In the era before homeowners could flip a switch to turn on the heat or air conditioning, landscaping played an important role in the comfort of a home. People planted trees and shrubs in strategic locations to mitigate hot summer sun and cold winter winds, while making the most of cooling summer breezes and radiant heat from the winter sun.

What happened to this commonsense approach to landscaping? Perhaps it's simply expediency—trees get in the way during construction. Or perhaps it has to do with our culture's obsession with the perfect lawn. No doubt it has to do with our legacy of cheap electricity and fuel. When electricity was inexpensive and heating oil was fifty cents a gallon, conserving these resources wasn't a high priority.

The price we've paid for these attitudes is reflected in the looming global warming crisis. However, it's not too late to turn things around. Individual gardeners may think they can't make a real difference. But imagine if all—or even half—the estimated 91 million gardeners nationwide took steps to reduce their energy consumption. Each of us can do our part—in our own landscapes and by communicating the information to others.

The National Gardening Association promotes home, school, and community gardening as a means to renew and sustain the essential connections between people, plants, and the environment. Our school gardening programs encourage children to become good stewards of the earth and inspire curiosity about and respect for nature. We invite you to join our effort to leave the legacy of a healthy planet for generations of gardeners to come.

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