FACING OUR FUTURE

Adapting to Connecticut's Changing Climate

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A Series of Eight Documents Concerning Connecticut's Changing Climate

Biodiversity & Habitat
Fisheries
Forestry
Infrastructure
Natural Coastal Shoreline Environment
Outdoor Recreation
Water Resources
Wildlife

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STATE OF CONNECTICUT
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FACING OUR FUTURE: Biodiversity & Habitat Adapting to Connecticut's Changing Climate

"The Millennium Ecosystem Assessment (2005) concluded that: 'By the end of the twenty-first century, climate change and its impacts may be the dominant direct driver of biodiversity loss and changes in ecosystem services globally.' Historically, habitat and land use change have had the biggest impact on biodiversity across biomes. However, climate change is increasingly affecting all aspects of biodiversity, from individual organisms, through populations and species, to ecosystem composition and function". *6th Scientific Statement Impacts of Climate Change on Biodiversity*, Irish Committee on Climate Change, Royal Irish Academy

Implications for Biodiversity

Biodiversity can be defined as the sum of life and its processes including the variety of living plants, animals and other organisms, and the ecosystems in which they occur. In spite of its small size, Connecticut has a large diversity of plant and animal life, and it is the responsibility of the Connecticut Department of Environmental Protection (CTDEP) to be vigilant stewards in maintaining this diversity and the important habitats that support it. According to Connecticut's *Comprehensive Wildlife Conservation Strategy* (CWCS) dated October 1, 2005, Connecticut supports thousands of animal wildlife species, mostly invertebrates. Add to these an estimated 2,600 species of vascular plants and the biodiversity of such a small state is remarkable. This diversity is a reflection of the state's varied landscapes ranging from the coastal beaches and dunes bordering Long Island Sound to the summits along the Taconic range in the northwestern corner of the state. While the considerations herein are interrelated to the other fact sheets, this fact sheet focuses on how critical biodiversity and abundant habitat are to adaptation in a changing climate.

Habitats and species are always changing across time and landscapes. However, as a result of climate change, a ripple effect from a confluence of stressors may dramatically unfold in the region's habitats and within the variety of life these habitats support. Invasive species, non-native or exotic plants and animals have the potential to significantly impact New England's native and most delicate flora and fauna as the climate is altered. Fragmentation of habitat, changes in biological timing known as phenology, and other disruptions to the food web are all threats to biodiversity. Climate change is expected to increase the rate of extirpations of rare and endangered species by altering their habitat.

Twin flower, a northern wildflower, will likely be extirpated from Connecticut as temperatures warm.

Since the end of the last glaciations 15,000 years ago, Connecticut has experienced dramatic climate and vegetation changes, with a northward progression of open woodlands of spruce and pine to the oak forests that dominate the landscape today. This occurred in a

landscape unaltered by man's presence. Given the predictions of a more rapid period of warming, there is no doubt that Connecticut will look very different to future generations. The challenge that Connecticut is facing today is to decide where rapid climate change will have undesirable environmental consequences and how to preserve and maintain our critical habitats to accommodate the inevitable change. The future of Connecticut's natural resources and biodiversity are tied to environmental planning and responsible growth.

Habitats in Connecticut – The landscapes of Connecticut are influenced by its geological past. Natural processes of many kinds have contributed to its present structure. In general, Connecticut can be subdivided into several geologic regions. The eastern and western parts of the state are characterized by wooded hills and low mountains underlain by acidic gneisses and schists. These two regions are separated by the Connecticut Central Valley, a younger region of sedimentary and igneous rocks. Here, the broad floodplain of the Connecticut River and a north-south-trending spine of basalt, or the trap rock ridges, are distinctive. On the northwestern border of the state is another prominent valley, here underlain by marble bedrock.

During the past glacial period, Connecticut was entirely covered by thousands of feet of ice**.** When the glacier melted, part of the debris was left in place as glacial till, and part was carried by glacial melt-water and deposited as stratified sand and gravel in the river valleys and lowlands. This debris provided the material in which the current soils have developed. Connecticut's landscapes are also influenced by climate. From the southeastern coastal region to the northwest corner, there is a progressive decrease in average temperature and length of growing season. This climatic transition and the regional variation in soils have had a major influence on the natural vegetation and the land-use history of the state.

From a regional perspective, the predominant vegetation of Connecticut today is forest mostly dominated by oaks, beech, birch, maple, and hickories. In northwestern Connecticut, these forests grade into a zone of northern hardwoods, composed primarily of sugar maple, beech, and yellow birch. Hemlock and white pine are common and/or locally dominant throughout. The return of Connecticut to a forested landscape is a relatively recent event**.** As recent as the late 1800's, Connecticut's forests were mostly cleared, plowed**,** grazed, and clear-cut for charcoal production.

Currently, the major causes of changes in Connecticut's plant patterns are fragmentation by residential development, the infestation of invasive species, and imbalance of certain key species such as whitetail deer. The impacts to certain habitats can be quite dramatic. It is estimated that habitats such as pitch pine barrens and sand plain grasslands have been reduced to less than five percent of their pre-European settlement abundance. Both coastal beaches and dunes have been built upon, most of our tidal marshes have been ditched for mosquito control, and our rare, geographically restricted fens in the marble valleys have been over-run with invasive plants. In other parts of the state, the regeneration of forest trees has been significantly reduced by deer browse. In fact, there are forested areas in Fairfield County where the understory has been denuded of vegetation, with the exception of highly invasive plants such as garlic mustard and Japanese stilt grass. The negative impacts of deer over-browse on biodiversity and ecosystem health should not be underestimated. Wildlife and forest management are critical to the ability of habitats to adapt to rapid changes in climate. (Information about forest management can be found in the Forestry fact sheet. Additional related information can be found in the Fisheries, Natural Coastal and Wildlife fact sheets).

Pitch pine woodland in Hopeville Pond Natural Area Preserve under fire management restoration

Responsible Growth - Physical barriers for plant and animal migration once were mountains, oceans and unsuitable soil**.** Barriers now include urban, suburban and agricultural lands as well. As Connecticut's habitats change as a result of warming, maintaining connectivity for habitat is critical for plant and animal migration. Connecticut needs to manage biological corridors and link together large habitat blocks. This must be paired with early successional management, by maintaining shrub lands, grasslands, and other open habitats for colonization. Connecticut may have to create and/or allow space for the inland migration of tidal marshes as sea level rises. These decisions need to be made within a landscape context, across political boundaries, to allow plant migration and succession over time**.**

CTDEP's updated *Green Plan* (2007-2012), recommends better identification of sensitive ecological areas and unique features to help guide acquisition and preservation efforts by state agencies, regional planning agencies, local communities and nongovernmental organizations. Maintaining migratory links and conserving sensitive habitats must be made an integral component of land-use planning and development. This habitat specific planning must be coupled with the principles of responsible growth.

Grasslands – Connecticut grasslands are also under intense development pressure. These areas provide a breeding ground for migratory birds and habitat for a large number of State Endangered and Threatened species. Natural grasslands are undoubtedly one of the most imperiled habitats in Connecticut, experiencing a precipitous decline in their natural distribution and extent on dry, nutrient-poor sites. One of the long term projections resulting from climate change is expected to include periods of prolonged drought. Trees occurring on dry ridge tops and dry sandy soils may drop their leaves due to water stress and could be weakened and die. If this is the case, there may be an expansion of natural grasslands in these areas. Since native grasses are well adapted to habitats with high daytime temperatures and intense sunlight, there may be an expansion of warm-season grasslands, mitigating the dramatic losses that have occurred to this habitat over time. This however, depends on whether there is sufficient foresight and planning within the state to retain adequate open space for this to occur. (See the Wildlife fact sheet for details on the CTDEP's Grassland Habitat Initiative).

Warm season grasslands are now confined primarily to small openings on dry, sandy soils.

Phenology – Phenology refers to the timing of biological events, including flowering, breeding, and migration; in relation to climate. With warmer winters, Connecticut is expected to experience progressively earlier spring flowering than in the previous century. Observations of plant phenology over the past 30 years already document earlier flowering in North American plants by an average of six days. The earlier onset of bud burst, flowering, and fruiting may have impacts on timing-sensitive relationships with pollinators, seed dispersers and herbivores. Events that have long occurred in synchrony may become decoupled. This will affect the timing of wild and agricultural fruit production, migratory species survival, and predator-prey relationships.

Many private organizations keep written logs of phenological observations. Formal records of flowering dates document the arrival of spring in New England three days earlier in recent years than it did in 1975. Since early spring migratory birds feed on the variety of insects that eat early emerging leaves and buds, this type of shift could take on some importance. At this point the shift is not great enough, within a two week window of observable record, to impact the relationship of migratory songbirds and the insects that they feed on. However, monitoring has already indicated that some early arriving warbler species are being weakened because they are lacking the typical fat reserves

necessary for their long flights. It is conceivable that if their food sources are not available within the right window of time, some warbler populations will diminish. The success of these migratory species correlates to the timing of leaf-out and the associated emergence of insect populations that occurs in spring. (For more related information see the Wildlife fact sheet where bees and other pollinators are discussed).

Grassy glades such as this opening on a trap rock ridge have a large diversity of spring wild flowers.

Food Web – Nature's food web could be described as beginning with plants' usage of the sun's energy and carbon dioxide to create organic matter through the process of photosynthesis. In a simple food web, plant growth is consumed by herbivores, which in turn are consumed by predators. As an example, oak trees produce acorns that are eaten by rodents that are food for hawks and owls. Acorns are also an important food source for white-tailed deer and wild turkeys that are eaten by humans. Oak leaves are also grazed by certain caterpillars that are necessary for the survival of various birds. This gives oak trees an important position in the local food web.

At some point, animals and plants die**,** and their remains decompose into nutrients that are incorporated into the soil to be used again by plants. Although it sounds simple, no food chain is completely independent of another. These interdependent food webs are the means in which energy is transferred from one trophic level to the next. A trophic level is the natural position of feeding structure in which all life exists. It takes a greater number of lower-level species of flora and fauna to support the energy needs of the higher trophic levels. Many of these plant-herbivore relationships are unique, particularly among insects. As certain plants succumb to habitat changes altered by climate change, deer over-browse, and other stressors, the whole interconnected food web must adapt or risk the same fate.

In some instances, invasive plants, introduced by human activities and lacking natural controls, take advantage of the disturbances created by these stressors. Invasive species displace native species, change pollination relationships, and alter soil conditions. The Connecticut landscape is over-run with invasive plants such as garlic mustard, black swallow-wort, mile-a-minute and Japanese stiltgrass. Once established, many of these plants release chemicals into the soil, inhibiting the growth of native species, and allowing invasive plants to dominate the understory. Invasive plants do not provide food sources for wildlife and often form a monoculture that reduces the biodiversity of the forests. Numerous other invasive species that occur in warmer climates do not yet occur in Connecticut due to winter temperatures. With milder winters projected, many of these species could establish a foothold adding to the disruption of natural ecosystem function.

Mile-a-minute; a highly invasive plant newly introduced into Connecticut

There has also been a recent increase in forest pests such as wooly adelgid, an insect that is severely impacting our evergreen hemlock forests. The distribution of hemlock wooly adelgid seems to be limited by winter temperatures, but as the climate warms, the impacts to hemlock forests will progress northward. Connecticut's current agricultural crops will likewise face different and sometimes

more difficult infestations. The impacts of climate change on these and other plant stressors will likely increase over time.

Ecosystems are fragile. Just how fragile can be seen in reports on the latest large-scale species die-offs such as bees' colony collapse disorder or bats' white-nose syndrome. The loss of native pollinators or bats would have serious ramifications in the food web, ripple effects throughout the ecosystem including degradation of the health of other species and habitats, and serious economic impacts. What is causing these changes is yet to be understood. However, Connecticut's changing climate has the potential to stress our ecosystem in similar ways, with acute stressors creating tipping points that cannot be recovered from and longer term insidious changes that may go unrecognized for decades. Whether to invest in keeping common species common is a choice associated with some risk. There will be some difficult decisions to make concerning adaptive management in the course of the next decade.

What Connecticut Is Doing

As we adapt to a changing climate, biodiversity and habitat protection are at risk. The actions we take today will be the key to conserving the wide array of life forms and habitats found in Connecticut tomorrow.

Endangered Species Protection – The CTDEP performs hundreds of environmental reviews each year to determine the impact of proposed development projects on state-listed species and to help landowners conserve the state's biodiversity. State agencies are required to consult with the Natural Diversity Data Base (NDDB) to ensure that any activity authorized, funded or performed by a state agency does not threaten the continued existence of endangered, threatened, or special concern species.

Habitat Management – The CTDEP has been a national leader in tidal wetlands restoration, removing large infestations of common reed *(Phragmites)*, a highly invasive plant, from this highly-altered ecosystem. By restoring these marshes to native plant populations, seed sources of native species will be naturally available for colonization of upland areas flooded by sea level rise. The CTDEP has also been active in restoring and maintaining grassland habitats through prescribed burning and invasive species removal.

Information Management – The CTDEP is collaborating regionally to determine the best method to standardize the nomenclature used in defining habitats. In this way, scientists can more easily share data through computerized Geographic Information System (GIS) mapping, and work regionally to protect habitats that contain both endangered and threatened species as well as commonly occurring species. The ability to efficiently share data will become more critical as climate change occurs and data must be shared more broadly to help inform decision makers.

Land Acquisitions – The state's goal for open space protection, prescribed by statute, is to preserve 21% of Connecticut's land, or 673,210 acres, by the year 2023. As of January 2006, 70% of this goal had been achieved. The CTDEP, through its Land Acquisition Division, has two programs available to assist in achieving this goal: The Recreation and Natural Heritage Trust Program and The Open Space and Watershed Land Acquisition Grant Program. By revising the criteria used to select properties for acquisition, the CTDEP can utilize these programs to prepare for the impacts of climate change by acquiring critical habitat for species of greatest conservation need.

The Recreation and Natural Heritage Trust Program is the State of Connecticut's dedicated, permanent fund for acquisition of land as additions to the state's system of parks, forests, and wildlife, fishery and natural resource management areas. The Recreation and Natural Heritage Trust Program is intended to: (1) acquire land that represents the ecological diversity of Connecticut, (2) acquire land of unusual natural interest as additions to the system of parks, forests, wildlife and fishery management areas, natural areas and dedicated natural area preserves in the state, (3) acquire land identified as essential habitat for endangered and threatened species, (4) offset carbon dioxide produced through combustion of fossil fuels by preserving lands that naturally absorb it, and (5) establish a stewardship account to provide for the maintenance,

protection and management of lands and the species that inhabit them.

The Open Space and Watershed Land Acquisition Grant Program provides financial assistance to municipalities and nonprofit land conservation organizations to acquire land for open space and to water companies to acquire land to be classified as Class I or Class II water supply property. Grants may be for the purchase of land that is: 1) valuable for recreation, forestry, fishing, conservation of wildlife or natural resources, 2) a prime natural feature of the state's landscape, 3) habitat for native plant or animal species listed as threatened, endangered or of special concern, 4) a relatively undisturbed outstanding example of a native ecological community which is uncommon, 5) important for enhancing and conserving water quality, 6) valuable for preserving local agricultural heritage, or 7) eligible to be classified as Class I or Class II watershed land. All of these criteria have adaptation co-benefits.

Recent Acquisitions – The CTDEP acquired 195 acres of land abutting the Massachusetts border that was historically used for tobacco farming. Since the property consists of wide open fields, and is located near the Connecticut River, the land is perfectly suited for grassland bird habitat. The Commonwealth of Massachusetts is working to acquire an additional 250 acres that abuts this property to the north.

In addition, several parcels of land have been acquired by the CTDEP since December 2007 for the protection of the endangered timber rattlesnake. Ranging from two acres to 148 acres, the properties were all added to the Meshomasic State Forest in the Towns of Glastonbury, East Hampton and Portland. The total combined area of the land is nearly 313 acres.

Property Selection – To assist in the acquisition of these important locations, an evaluation system is necessary to ensure that the state acquires properties which are of exceptional value in each of the above categories, and to ensure reasonably equal distribution in functional ecosystems. This rating system is used to evaluate land offerings to the state and to prioritize the worth of prospective purchases. In conjunction with an assessment of statewide needs, this evaluation system is also used to develop acquisition plans that meet the environmental criteria for habitat and biodiversity conservation.

This is one of eight documents in the series *Facing our Future* concerning Connecticut's changing climate, www.ct.gov/dep/climatechange

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IMPROVEMENTS AND CHALLENGES FOR TODAY

Individual, Corporate, Municipal and State Stewardship

- Use a Geographic Information System (GIS) to view the University of Connecticut's Center for Land Use Education and Research (CLEAR) data that reveals land cover information from satellites and includes 11 cover types: developed, turf and grass, other grasses and agriculture, deciduous forest, coniferous forest, water, non-forested wetland, forested wetland, tidal wetland, barren and utility rights-of-way.
- Identify the location and quality of existing grasslands and lands suitable to create grasslands.
- Protect grasslands in order to reduce the number of state threatened and endangered grassland bird species.
- Support acquisition of wildlife habitat under CTDEP's Open Space Acquisition Plan.
- Submit a property for consideration for purchase by the CTDEP that is a unique, natural area or habitat http://www.ct.gov/dep/lib/dep/open_space/LandAcquisApp.pdf
- Improve the dissemination of information among state and local official and landowners.
- Support proactive management of invasive species by municipalities. Control at town facilities is our first line of defense. Housekeeping such as cleaning off equipment needs to be a routine practice.
- Provide educational outreach about simple methods to avoid the further spread of invasive species.

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE: Fisheries
Adapting to Connecticut's Changing Climate

"Thermal tolerances for cold water fish like salmon, trout, alewives (herring) are likely to be exceeded in the northeastern USA resulting in significant reductions in suitable habitat. Other species will thrive in warmer waters."

Impacts of Climate Change on Hydrologic Regimes: Implications for the Northeastern U.S. at the New England Interstate Water Pollution Control Commission (NEIWPCC), June 26, 2008, presentation by the United States Geological Survey (USGS)

Implications for Fisheries

Climate change is expected to cause a general increase in average temperatures, causing Connecticut's climate to be similar to that of New Jersey under the reduced emissions scenario, and more like Virginia under the high emissions scenario. There are also anticipated changes in rainfall patterns and severity of storm events, amount of snow pack, and timing of snow melt and spring freshets in rivers along with changes in riparian vegetation and location of salt wedges in Connecticut's major rivers. Furthermore, water temperatures will continue to increase in freshwater and Long Island Sound. With these increased water temperatures New England can expect the abundance and distribution of coldwater species to decline and warmwater species to increase. This will have consequences for how Connecticut manages fisheries and fish habitat.

A total of 168 species of fish (63 freshwater and diadromous, and 105 saltwater) are found in Connecticut, including seven species that are recognized to be of special concern, threatened or endangered (*Connecticut's Comprehensive Wildlife Conservation Strategy*, 2005). As with terrestrial species, Connecticut is experiencing subtle but documented shifts in its freshwater and marine fisheries resources. As a result, climate change is something Connecticut currently must consider when implementing Connecticut Department of Environmental Protection (CTDEP) fisheries programs and regulations.

In Connecticut's freshwater environment anadromous and coldwater fish species will likely be the first and most severely impacted by a warming climate. Earlier snowmelt and the timing of the annual spring freshet may inhibit or reduce spawning of native fish such as american shad, alewife and blueback herring. A recent review of the historical records on the timing of the spawning migration by alewife in the Connecticut River revealed that it is occurring 12 days earlier than during the 1970's. More southerly occurring anadromous fish species such as hickory shad and gizzard shad have become common visitors to Connecticut coastal streams.

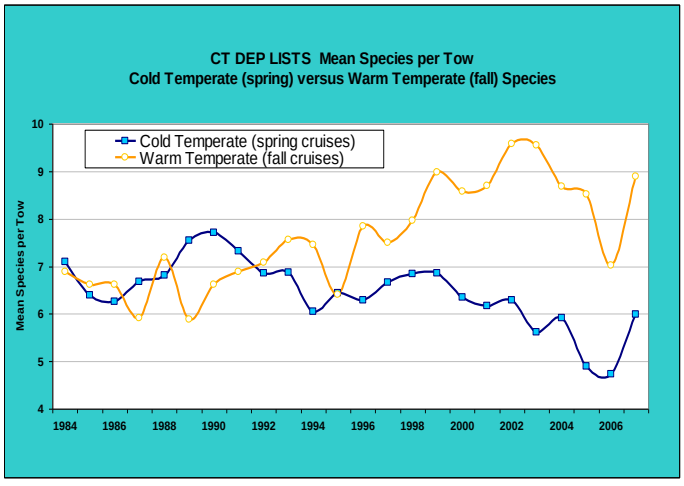
Due to development and its impacts on water temperatures and stream flow, Connecticut has experienced a dramatic decrease in coldwater fish habitat that supported native stream dwelling species such as the eastern brook trout. It is currently estimated that less than 2% of Connecticut's 23,000 km of stream hold healthy wild brook trout populations. This change has occurred most notably in Fairfield and New Haven Counties. According to a recent publication, *Eastern Brook Trout: Status and*

Threats, 2006, "Brook trout serve as indicators of the health of the watersheds they inhabit. Strong wild brook trout populations demonstrate that a stream or river ecosystem is healthy and that water quality is excellent. A decline in brook trout populations can serve as an early warning that the health of an entire system is at risk". Fragmentation of migratory corridors by dams and low flows has reduced the ability of fish populations to adapt to temperature change. Further stress on Connecticut's coldwater habitat is one of the major anticipated repercussions of a warming climate.

In a recent study of the Connecticut River, a continuous trend toward increased water temperatures, from the mid-1970's to 2003 was concurrent with observed shifts in the predominant fish species. Sunfish species that were rare, or absent, are now abundant (rockbass, redbreast sunfish, and pumpkinseed sunfish) and catfish species have undergone a dramatic shift (channel catfish have replaced white catfish and brown bullhead). The degree to which these changes are the result of increasing temperatures is uncertain. However, it is likely that warming will cause additional adjustments in the Connecticut River's fish populations.

Connecticut lakes are currently undergoing tremendous development related pressure. According to CTDEP's 1996 *Caring For Our Lakes, "*Under natural conditions eutrophication is the natural aging process of lakes that occurs over a long period. [An undisturbed] forested watershed contributes minimal amounts of nutrients and sediments, and takes centuries to change a lake's appearance. The aging process speeds up considerably, however, when the amount of nutrients and sediments that drain into a lake increases due to development, farming, and other human activities. The term commonly used when eutrophication is accelerated by these man-made conditions is cultural eutrophication." Land use in the lake watershed is tied directly to the rate at which the lake ages or eutrophies. Projected increases in water temperatures and a longer growing season will accelerate the balance between nutrient dynamics within the lake and its watershed and can lead to increased algal blooms and aquatic plants that die and deplete oxygen. Increased rates of eutrophication lead to a loss of habitat for coldwater species such as trout and coolwater species such as walleye and northern pike.

Water temperature in Long Island Sound has been increasing. Continuous temperature readings at Millstone Point in eastern LIS show a 1.3^{o}C increase since 1976. Bottom temperature readings taken through the middle of the Sound since 1991 show a similar increase. Concurrent with the temperature increases, the Long Island Sound Trawl Survey (LISTS) has documented a significant decline in the overall abundance and average number per sample of "cold temperate" species captured in the spring, and a significant increase in the occurrence of "warm temperate" species. LISTS cruises now encounter an average of 10-12 warmwater species per sample during the fall survey compared to just seven to nine species per tow when the survey began in 1984. Of 11 cold temperate species in decline, winter flounder is the most widely known and heavily fished. However, other cold temperates in decline include the longhorn sculpin, sea raven and cunner - species experiencing very little or no recreational or commercial harvest. Smelt and tomcod are two other cold temperate species in severe decline, based on research conducted by the University of Connecticut, and they are identified as species of special concern.



Another local species that has declined concurrent with the regional warming trend is American lobster, a boreal species at the southern boundary of its range. The Long Island Sound lobster population experienced a severe mortality event in 1999. In the summer of 1999, bottom water temperatures were 1-2^{o}C warmer than average, exceeding the lobsters' stress

threshold temperature (20°C or 68°F) for weeks. The CTDEP's Long Island Sound Water Quality Monitoring Program (LISWQMP) has generated monthly water temperature and dissolved oxygen profile maps of Long Island Sound since 1991. To add fine-scale detail to these maps, Marine Fisheries staff initiated a cooperative program with commercial lobstermen who have set continuous temperature recorders in their lobster traps beginning in 2006. Recognizing 20°C as a stress threshold for lobster and possibly other cold temperate species, the number of days when continuous readings averaged above this value has been recorded. In 2006 and 2007, daily average water temperatures exceeded this stress threshold 4-16 days in Long Island Sound's eastern basin; 51-66 days in the central basin; and 55-73 days in the western basin. As average water temperatures increase the increased seasonal abundance of some mid-Atlantic fish species will create opportunities for fishermen. However, the blue crab that thrives in mid-Atlantic temperatures has not shown a consistent increase in abundance locally since most winters remain too cold for good overwinter survival. The CTDEP's Water Bureau and Marine Fisheries Division staffs are collaborating with University of Connecticut faculty to continue to assess the implications of these temperature patterns.

The Food Web that supports all finfish may be altered by climate change in ways that humans are only beginning to understand. When phytoplankton, zooplankton or fish grazers are differentially impacted by climate change, cascading impacts on the structure of the food web may result. Harmful algal blooms, which can be toxic to fish and shellfish, may become widespread. Fortunately, to date only one extensive bloom of a potentially harmful species (the dinoflagellate *Prorocentrum minimum)* has occurred in Long Island Sound. In the summer of 1987, this species disrupted the planktonic and benthic food webs in the western Sound from New Haven to the East River, NY. Since that time, all other algal blooms in the Sound have been localized and of short duration. However, continued increases in environmental fluctuation causing alterations in land runoff, water column stratification or acidification may allow harmful algal species greater opportunity to dominate Long Island Sound's plankton community. Algal blooms in freshwater lakes may also increase with a longer growing season and with the direct impact of higher temperatures result in further reductions in dissolved oxygen and coldwater fish habitat. (Additional information about the food web can be found in the Biodiversity fact sheet).

Both freshwater and saltwater marshes and wetlands are vital to local fisheries production. Not only do these areas act as sponges for water retention and buffers against the impacts of severe rainfall, storms and pollution events, they are also important nursery areas for many aquatic species. For example, in the freshwater environment, wetlands perform the critical function of regulating flows that help to cool headwater streams during the low-flow summer months. Wetland areas also provide sources of nutrients. These nutrients promote primary production which in turn provides a food source for aquatic invertebrates and insects, the basis of the food web for fish. In the marine environment, small killifish enter brackish water marshes on high tides in large numbers to consume marsh invertebrates that feed on decaying marsh grasses. The killifish then migrate to coastal waters where they become prey for fish like fluke, stripers and bluefish thereby exporting marsh energy to open marine waters. If the marshes and marsh grasses are drowned or degraded by sea level rise or severe storms, all the associated species along the food chain will also be affected. (For additional wetlands related information see the Natural Coastal and Water Resources fact sheets).

Invasives – A warming climate will likely create a more conducive environment for invasive species. Aquatic invasive species (both plant and animals) have been a long-standing problem in both the freshwater and marine environments. Many of these invasives have been unintentionally introduced from ballast water transfers of ocean going vessels and through the live bait, pet trade, and water garden industries. Invasive species often proliferate at alarming rates due to the lack of the natural controls or predators that kept their populations in check in their native range. Once aquatic invasive species become established they are often relocated by recreational boaters. Boats, contaminated with aquatic plants or animals from one area, can introduce nuisance problems

to other locations, when these invasives 'hitchhike' to new lakes and rivers. The introduction of zebra mussels into East Twin Lake in the late 1990's is but one example of a recent invasion. The spread of Eurasian water milfoil, an invasive aquatic plant, throughout the state is an example of how an invasive can cause widespread damage.

What Connecticut is Doing

The CTDEP's Inland and Marine Fisheries Divisions are working to protect, restore and enhance fish habitat so that fish populations have as great an opportunity as possible to adapt to a changing climate.

Overcoming fragmentation of populations by providing migration access to upstream spawning habitat and potentially cooler water temperatures is essential for the continuation of diadromous and stream-dwelling coldwater fish species. The CTDEP's Inland Fisheries Division provides technical guidance in designing fish passage facilities. For example, fisheries restoration in 2008 included fabricating and installing a new eel pass at the state-owned Bunnells Pond Dam (Pequonnock River, Bridgeport). This eel pass, with a new design, is expected to greatly increase the number of eels able to get over the nearly 30 foot high dam. The CTDEP assists in the completion of approximately three fish passage projects per year (fishways and eel passes) that successfully open up large stretches of previously inaccessible riverine habitat. Providing "connectivity" to resident populations of fish in smaller streams, especially during low flow periods of the year, is accomplished by taking advantage of opportunities to remove barriers to fish migration including dams, improperly installed culverts and other obstructions. Furthermore, the CTDEP requires that thermal discharges minimize the impacts to fish habitat. In the broader context of maintaining diverse habitat, the CTDEP is in the process of developing comprehensive stream classification criteria and stream flow regulations designed to maintain fish communities.

With a changing climate will come changes to recreational fishing, in both the marine and freshwater environments. Once common, species such as winter flounder may become less common while other, more adaptable species flourish. Freshwater fish such as trout may not be as plentiful, or available at all, in former locations. Connecticut will need to invest in habitat protection where appropriate, especially with cold, headwater streams that still support healthy populations of native, eastern brook trout. The recent implementation of a statewide Trout Management Plan (2002) based on stream survey data that identifies valuable cold water resources is a step in the right direction. Subsequent resource protection will be critical such as with the Belding Wildlife Management Area where the headwaters of the Tankerhoosen River are found. This stream supports a healthy, self-sustaining population of native eastern brook trout and wild brown trout.

The CTDEP's three trout hatcheries currently produce approximately one million trout annually. These fish are distributed into lakes and streams with suitable coldwater habitat and support a very popular recreational resource. The CTDEP is considering opportunities for further stocking of warm water species and alterations of state hatchery management practices to support these opportunities as the climate changes. Despite the observed and projected future changes due to a warming climate, Connecticut's freshwater fisheries resources are well poised to adjust to changing conditions by utilizing naturalized populations of cool and warmwater species such as northern pike, walleye, channel catfish, and largemouth and smallmouth bass. Proactive management of species in addition to trout will ensure maintenance of diverse freshwater fishing opportunity throughout the state. (See the Outdoor Recreation fact sheet for information about fishing programs).

Monitoring – Conducting monitoring programs to assess the status and health of populations and habitat, and re-evaluating those programs to determine if they should be modified, will help Connecticut understand how a changing climate is affecting fish communities and habitats. This information will help the CTDEP adapt fishery management and habitat conservation programs to more effectively respond to variations caused by climate change.

The CTDEP's Marine Fisheries Division supports several long-term monitoring programs

that are vital to understanding the impacts of climate change and associated geographic shifts in species distributions as well as to the practice of ecosystem-based fishery management in the face of a changing environment. These programs include the Connecticut River Shad Study beginning in 1979, the Connecticut Larval Lobster Survey beginning in 1983, the Long Island Sound Trawl Survey beginning in 1984, the Connecticut Estuarine Seine Survey beginning in 1988, and the Long Island Sound Water Quality Monitoring Program (LISWQMP) beginning in 1991. These long-term monitoring programs are positioned to provide a quantitative context for effects of climate change on key marine species and life stages.

The CTDEP's Inland Fisheries Division has also been involved in long-term monitoring of inland fisheries resources. This monitoring includes the Lake and Pond Survey beginning in 1988, Stream Survey beginning in 1988 and Diadromous Fish Enhancement and Restoration beginning in the late 1970's. University of Connecticut researchers have recently completed a four-year survey of striped bass and river herring populations in the Connecticut River. Information on striped bass consumption rates, striped bass abundance, and river herring population structure derived from these field studies will be used in a population modeling analysis.

As waters continue to warm Connecticut will need more focused monitoring of habitat conditions and species' abundance to ensure healthy and diverse fisheries for years to come.

Action is Needed Now

Steps can be taken now to help Connecticut's fisheries resources adapt to a warming climate. The acquisition and protection of critical coldwater, and wetland habitat, along with migratory corridors, will help mitigate the effects of a warming climate. New ways to control or limit the effects of stressors will be sought wherever possible. Preventing the introduction of new aquatic invasive species and limiting the spread of currently existing ones is one example. Continued and expanded programs to monitor both marine and inland fisheries resources will be critical to providing timely information on the effects of climate change.

This is one of eight documents in the series *Facing our Future* concerning Connecticut's changing climate, www.ct.gov/dep/climatechange

DEPARTMENT OF ENVIRONMENTAL PROTECTION
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IMPROVEMENTS AND CHALLENGES FOR TODAY

Individual, Corporate, Municipal and State Stewardship

- Avoid fragmentation of habitat, stream channel modifications, adverse water level manipulation, adverse diversion, filling, dredging, impoundment, sedimentation and nutrient loading, removal of riparian vegetation, excessive vegetation control, and shoreline modification.

- Support land acquisition and conservation easements containing critical habitat and head waters.

- Support monitoring programs focused on climate change that will provide the needed information to guide effective management actions.

- Expand efforts to prevent, eradicate, and control invasive aquatic species.

- Continue proactive efforts to develop and enhance fisheries for temperature tolerant species.

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE: Forestry
Adapting to Connecticut's Changing Climate

"The challenge for the future is how to sustain the delivery of goods and services people expect from Connecticut's forest resource while addressing problems associated with increasing land development controlling introduced pests, diseases, and invasive exotic plants; and manage the lack of regeneration of desirable tree species such as oak." *The Forests of Connecticut*, United States Department of Agriculture, 2004.

The Importance of Connecticut's Forest

With over 3.4 million citizens living on 3.2 million acres of land, Connecticut is one of the most densely populated states in the country. At the same time, with some 1.8 million acres covered by forests, the percentage of the state that is forested is also among the highest in the country. Connecticut is truly a state of forest-dwellers, and it is this forest that touches virtually every aspect of the quality of life in the state. Connecticut residents are becoming more aware that a sustainable forest provides not only wood but clean water, clean air, shading, cooling, critical habitat, recreational opportunities, and carbon sequestration.

Some of these benefits of the forest to the people of Connecticut are direct and tangible. The state's forests are responsible for filtering and protecting the quality of Connecticut's drinking water and for cleaning ambient air. The public and private forests provide innumerable state residents with opportunities to hike, hunt, camp, and fish. The forest products industry in Connecticut contributes 500 million dollars annually to the state's economy. The beauty of the state's forests, particularly in the fall, draw in enormous numbers of tourist dollars to the state.

Some of the benefits of this forest are less tangible. Trees, individually and collectively, provide a strong sense of place to people, and the extensive forest all around Connecticut are a part of what typifies the state to its people. While the degree to which the forest cleans the air or the water can be quantified, the exhilaration felt by an individual in the woods breathing that air and crossing those streams cannot be, at least not readily.

Carbon Sequestration - A well managed forest is a valuable carbon sequestration tool. A well-adapted, diverse, healthy forest will promote a growth rate per tree directly linked to maximizing mitigation of carbon dioxide, a greenhouse gas, through carbon sequestration.

A Brief Snapshot of Connecticut's Forest

Connecticut's forests have always been in a process of change, ever since the first tree seeded following the retreat of the last glacier. To some extent, a forest is simply the sum output of the dynamic forces that shape it – including climate, soil, species, weather, and

human history. This is true of the forest of today and this will be true of the forest of tomorrow.

A brief snapshot of the forests currently in Connecticut would show a remarkable diversity in tree species including representatives of the more southerly oak-hickory forests (oaks, hickories, red maple, etc.) and of the northern hardwood forests (sugar maple, yellow birch and beech). Connecticut's forests also have a significant coniferous component, including eastern white pine and eastern hemlock. The great number of tree species that have their range overlap in Connecticut is indeed unusual.

At the same time, the forests in Connecticut are old, in the sense that a majority of the individual forested acreages are filled with mature trees. While there is a diversity of species, there is not a diversity of age classes. As the health and the resiliency of the forest often depends upon both species diversity and a diversity of age classes, the ability of Connecticut's forest to respond to stress and changing conditions is mixed. This lack of diversity in age class may become more of a factor as climate change affects the overall condition of the state's forests.

Forests in Connecticut have long been under stress due to many factors. These stresses include a legacy of extensive land-clearing from the past three centuries, often followed by poor woodland management as the forest returned; a history of severe forest disruption due to the introduction of exotic pests such as the chestnut blight, the gypsy moth and the hemlock woolly adelgid; and, in more recent times, trends such as urban sprawl invading the forest, changing ownership patterns dividing the forest and exotic plant species moving into the forest and displacing native species. Take these stressors and add climate changes, such as increasing temperatures and changing hydrology and it is reasonable to expect ecological and economic challenges for years to come.

Implications of a changing climate for the Forests of Connecticut

Climate change may affect Connecticut's forests in the following ways.

Species composition - As Connecticut gets warmer in terms of relative annual highs and lows of temperature, the competitive advantage that certain tree species have over other trees' species will likely increase – with those species in the more southerly oak-hickory mix likely gaining an advantage over those in the northern hardwood mix. Overall, there is likely to be a decrease in the diversity of tree species in Connecticut's forests. This change in tree composition will likely influence similar changes in the occurrence of plant and animal species dependent on forest type. Of course, the temperature changes will not occur in complete isolation; climate change will interact with these other factors, often in ways that are subtle and difficult to connect. (For more details related to habitats, phenology and wildlife see the Biodiversity and Wildlife fact sheets).

Exotic Pests - A very strong case can be made that one major forest pest of current concern, the hemlock woolly adelgid, will thrive as the climate changes. This highly destructive insect, a recent introduction, is regularly held in check by cold winters. Warmer winters will likely allow the population of this insect to increase dramatically, although loss of the hemlock host or the emergence of predators on the insect could cause the opposite effect.

Climate change and changing forests will likely lead to new opportunities for exotic pests – insects, diseases, plants or animals. Climate change will likely accelerate the rate at which changes occur in the forest. Increased human commerce will expose these forests to increasing numbers of pests that can take advantage of the opportunities that change brings.

Weather - The trends in weather patterns projected as a result of a changing climate, if they occur as projected, will certainly have significant effects on Connecticut's forests.

The projections are for more intense storms, including seasons in which precipitation will be more intense followed by periods of extended drought. High winds generated from intense storms combined with heavy precipitation and flooding, such as occurred in the 1938 hurricane, can lead to the extensive destruction of large stands of trees. When these events are followed by extended drought the number and intensity of wildfires can be greatly increased. Fire releases carbon dioxide, causes increased health risks and damages property. Longer periods of drought make unhealthy forests especially vulnerable to fire. Subsequent flooding erodes nutrient rich soil and limits the types of tree species that can propagate in the area. (For more details on flooding see the Water Resources and Infrastructure fact sheets). Each of these types of weather-related events presents challenges to forest management.

The Forest Economy - For the forest products industry in Connecticut, changes in species composition might create new markets and could close out old ones. Longer growing seasons might mean that trees will grow faster and produce more wood, or that the exposure to the extremes of fire and weather will cause greater losses in the woods. An exotic pest might completely bring a promising opportunity to a halt, the way the chestnut blight ended the anticipated commercialization of chestnut in the early 1900's. The forest products industry will need to be adaptable and intelligent if it is to survive and thrive through change that will come to the region

Biomass - The forests contain a significant amount of biomass. This woody debris decays and slowly releases carbon dioxide. Yet, harvested biomass provides a relatively untapped and attractive financial opportunity as a local fuel. Active forest management that includes harvesting biomass using best management practices shows considerable promise as a strategy for forest managers to use in the reduction of invasives, forest pests and disease; to improve wildlife habitats and to restore high-graded areas. Overactive or improper harvesting can deprive the soil of nutrients, spread invasives that propagate through cutting, destroy wildlife habitat, and reduce biodiversity. Biomass has a significantly lower carbon footprint than many other fuels. However, burning biomass can result in excess emissions of particulates and other air pollutants under certain conditions.

In order to maximize the utility of burning biofuel as an adaptative and mitigative approach to climate change it must be balanced with air quality and forest management concerns. Local outlets for biomass as a fuel need to be proactively managed as biomass harvesting becomes more attractive economically. The infrastructure that active biomass management creates will have the added benefit of providing an outlet for storm related debris, a need that may grow with projected increases in storm frequency.

As for other aspects of the forest economy, clean water, clean air, recreation and the value of real estate; it is quite likely that the relative value of each of these will increase as the climate changes and as the human population continues to make demands on the use of these resources. Enhanced forest management can increase this value. (For more on the relationship of land use management to water quality see the Water Resources fact sheet).

What does all of this mean? In the absence of change that is known, specific, and definable, it is important that Connecticut chooses options that maintain ongoing, close contact with the forest by qualified managers. For the forest to be sustained in a manner that maintains the health and sustains the benefits derived from the forest, those active in the forest will need to be observant and adaptive in their actions as the impacts of climate change reveal themselves.

What Connecticut is Doing

The Connecticut Department of Environmental Protection (CTDEP) Division of Forestry has an active program of forest management in place for the state's 170,000 acres of state-owned forestland. The purpose of this program is to enhance forest health, wildlife habitat and recreational opportunities on these lands, and to sustain those benefits for the generations to

come. This program is based on the insight and experience of more than a century of public forest management in Connecticut. Managing these lands not only provides a core of well-maintained forests for the state; this activity also serves as a model for proper forest land management for other land owners in Connecticut. Among the recent innovations in this program, the Division of Forestry along with the Wildlife Division is working with the University of Connecticut's Nonpoint Education for Municipal Officials (NEMO) program to map the state-owned forests and wildlife management areas, in an effort to enhance land use planning, wildlife research and forest management.

CTDEP Division of Forestry also regulates the community of forest practitioners who are engaged in carrying out forest management activities on private and public lands throughout the state. The forest practitioner certification program establishes standards for proper forestry and harvesting activities within the forests, and, through an enforcement program, takes steps to ensure that forestry activities are in accord with these standards. Foresters certified by the Division of Forestry regularly develop comprehensive forest management plans for more than 20,000 acres each year.

The outreach services of both the CTDEP Division of Forestry, through the Private and Municipal Land program, and the University of Connecticut Cooperative Extension Forestry Program provide a critical link between private forest land owners and the professional forestry community. After all, on private lands, it is the decision of the land owner that is pivotal in the long term outcome. Planning is not enough, Connecticut has to engage the land owners to be successful with large scale forest management.
The scientific community within Connecticut is also key to maintaining this close, ongoing contact with the forest. The Connecticut Agricultural Experiment Station has long-term study plots to monitor forest growth and changes, and is in the lead in responding to the threats caused by forest pests and diseases. As home to a substantial Connecticut crop, the health of forests will continue to be monitored for adaptative strategies.

The Yale University School of Forestry and Environmental Studies is assisting CTDEP Division of Forestry with determining responsible forest harvest levels that will increase the Division's ability to manage the forest to generate a sustainable yield. The School of Forestry has indicated that revenues from state-owned forested lands can be tripled by improving potential product yield. Doing so will encourage biodiversity that improves the capability of Connecticut's forests to respond to the stresses brought about by climate change. More active management is better for the forest economy and is needed to be responsive to changes brought about by climate. If Connecticut doesn't rectify forest management practices undue stress will be put on the forests and the habitats they support. Active forest management will also enhance our forests' ability to act as carbon sinks, an important climate change mitigation strategy.

Other programs within the CTDEP Division of Forestry also have significant roles to play with respect to climate change. The fire and forest health programs monitor changes in the forest, such as those brought about by drought, fires, pests and invasive plants

The urban forestry program encourages healthy urban forests that help bring the benefits of trees to those who live in the more urbanized parts of the state, including the inner urban core, newly developed subdivisions and all points in-between. A recent study conducted by CTDEP Division of Forestry along with the City of Hartford, the Knox Parks Foundation and the US Forest Service found that the trees within the limits of Hartford remove about 2,440 tons of carbon a year from the atmosphere, and lock away that carbon for the life of the tree. These trees also provide localized protection from the heat of summer and the cold of winter to an extent that reduces residential energy use by the equivalent of about 2,400 barrels of oil annually. The study also showed that the trees of Hartford filter out about 37 tons of particulate matter a year, eight tons of carbon monoxide, seven tons of nitrogen dioxide and four tons of sulfur dioxide annually. By shading and cooling our streets, trees remove or help prevent the formation of about 15 tons of ozone each year. By improving life in our urban areas, the urban forest encourages reinvestment in existing urban

and suburban centers, and takes developmental pressure off of the more traditional woodlands of Connecticut.

In conclusion, it should be reemphasized that Connecticut's forests play an important mitigative role against the expected harmful effects of climate change. Trees shade homes and businesses during the summer, cleanse the air by intercepting airborne particles through respiration, and act as carbon sinks by storing carbon dioxide in the wood, roots and leaves. Connecticut can maximize these benefits by keeping forests as forests through proactive land conservation, land-use planning, and seeking professional forestry assistance to maintain vigorous and resilient forested conditions. Connecticut forests will be better able to adjust to the changing climate through the efforts of supporting agencies and organizations engaged in technical assistance and educational outreach activities where the latest in best management practices are shared with the forest land owners who, as a group, own over 1.5 million acres of Connecticut's open space woodlands.

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
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IMPROVEMENTS AND CHALLENGES FOR TODAY

Individual, Corporate, Municipal and State Stewardship

- Support land acquisition containing critical habitat and head waters.
- Increase forest management activities to enhance age class diversity.
- Establish monitoring protocols.
- Preserve and manage as much traditional woodland, urban forest, shrub land and grassland as possible, including the significant holdings on privately owned lands.
- Encourage and maintain tree diversity.

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE: Infrastructure

Adapting to Connecticut's Changing Climate

"The Northeast suffered an estimated $130 million in property damage from several intense storms in the fall of 2005 and spring 2006. Connecticut's coast has almost $405 billion of insured coastal [assets]. ... Coastal homes, roads, and infrastructure are at increased risk as sea level rises and storms become more intense. Scientists, insurers, investors, planners, designers, and policy makers must respond to the significant consequences of climate impacts on human health, coastal infrastructure, ecosystems, agriculture, and the economy."

Connecticut's 2007 Natural Hazards Mitigation Plan

Implications of a Changing Climate On Connecticut's Infrastructure

A changing climate will impact Connecticut's infrastructure as the resiliency of the built environs will be tested repeatedly over the coming years. Conversely, the infrastructure can serve to magnify or mitigate the anticipated effects of climate change on both the natural and human habitat depending on location, design and most significantly, Connecticut's preparedness and ability to adapt to those changes.

To prepare for climate change, Connecticut must take stock of its primary infrastructure that includes recognizable features such as homes and neighborhoods, and the bridges, roads, railroads, schools, airports, ports, water supply treatment systems and reservoirs, sewage treatment plants, power plants, transmission lines, and recreational, industrial and commercial facilities that support Connecticut's economy and lifestyle. Successful adaptation will require that Connecticut consider many more less recognizable landscape features as integral components of "infrastructure." Landscape features can buffer the built infrastructure from damaging natural weather events while maintaining water supplies and the vitality of the ecosystems that rely on good quality and adequate quantity of water. Connecticut must begin to assess risk and set adaptive action priorities for both. These adaptation choices for the built environment and the underlying landscape will affect communities and their citizens, historic and cultural resources, the economy, and the natural environment. While the adaptation considerations for Connecticut's infrastructure are interrelated with the Water Resources and Natural Coastal fact sheets' content, which emphasize existing variables and potential impacts of a changing climate on natural resources and habitats, this fact sheet focuses specifically on the vulnerability of infrastructure in Connecticut's changing climate.

River Flooding - Flooding along rivers and streams is the number one natural hazard in Connecticut and its frequency is expected to increase as climate change alters precipitation patterns. The Intergovernmental Panel on Climate Change (IPCC) projects that there will be more frequent and intense storms for the Northeast region, which will increase episodic flooding. According to Connecticut's 2007 *Natural Hazards Mitigation Plan Update*, over 32,000 homes are located in the 100-year floodplain along Connecticut's rivers. These homes are at increased risk from flooding along with associated supporting infrastructure.

According to a 2003 report by the University of Connecticut, entitled *Precipitation in Connecticut*, there has been a statistically significant increase in precipitation amounts in

Connecticut over the past 100 years. This report analyzed precipitation data through August of 1996 in Connecticut that shows annual precipitation amounts have increased.

Flooding can significantly disrupt essential state and local services when infrastructure is damaged, destroyed or isolated, placing high demands on public safety officials. Billions of dollars in clean up and replacement costs of personal property and public infrastructure are at stake. Some communities have begun to look at adaptation options, but uncertainty in current projections and lack of adaptation strategies have resulted in limited action. As a first step, location of new or rebuilt structures must consider flood protection standards that are consistent with National Flood Insurance Program requirements and give consideration to projected storm frequencies and intensities.

Flooding may also impact or overwhelm both natural and modified landscape features designed to mitigate flooding and flood damage, including inundation and sedimentation of riverine wetlands, erosion of stream banks, damage to infiltration devices, and destruction of trees and natural vegetative practices used to control stormwater and nonpoint source runoff. Best management practices, including landscaping techniques as well as conservation, must include consideration of extreme conditions caused by changes in climate.

Coastal Flooding – The threat of more severe storms, combined with sea level rise, can result in increased infrastructure damage from coastal storm surges. Sea level rise projections vary, but moderate estimates from a 2001 report by the IPCC range from four inches to 2.9 feet by 2100, not considering the accelerated melting of ice sheets that has been observed in the past few years.

The choice between retreating and shoreline armoring will inevitably need to strike a balance between the natural and built environment. The living shoreline provides a natural buffer zone that is able to attenuate the impact of storms on coastal development while providing natural filters that protect coastal water and habitat quality.

Although hardened shorelines may be necessary to protect primary infrastructure they should be used sparingly as their protective value may be short lived and counterproductive.

Storm damage from the 1938 hurricane. Photo source: Connecticut 1938 U.S. Army Air Corps, Connecticut State Library Collection

New development siting should not assume a stable shoreline; storms and sea level rise will erode and inundate natural buffers thus increasing the threat of property damage. Further, protective landscape features narrow when pushed against development and are prevented from retreating inland. Preserving or restoring coastal features that help protect human infrastructure under today's conditions will not adequately provide those same services under changed climate conditions. To accommodate these needs, accelerated sea level rise will require a new look at Connecticut's underlying statutory and regulatory programs related to both coastal and inland water resources, landscape protection, and infrastructure and development placement to include the presumptive changes due to climate change.

Photo source: Connecticut 1938 U.S. Army Air Corps, Connecticut State Library Collection

Transportation - Major transportation corridors including interstate highways, rail lines, and ports are often located along Connecticut's river valleys and coast where they may be at risk from flooding and storm surge. Associated with this transportation infrastructure is also considerable landscape infrastructure that provides buffers for water protection, infiltration, drainage, and even fish and wildlife habitat, open space, and recreational opportunities in many cases.

The Connecticut Department of Transportation (CTDOT) is responsible for many state and interstate roads, highways and bridges, and the state's public transit system, rails, ports and some airports. Ports may need to be altered and roads, rails, and other transportation corridors redesigned due to sea level rise and threats from more frequent and more violent storms. Local authorities, similarly, have responsibilities for local roadways and transportation facilities and related structures such as marinas and roadway drainage systems through planning and zoning commissions and public works' departments.

Safety inspection procedures for bridges and other transportation infrastructure, including landscape and drainage features may need to be reevaluated for increased threats related to climate change. Transportation infrastructure not directly threatened by inundation or physical damage, such as erosion or scour, should nevertheless be comprehensively evaluated for its ancillary contributions to climate change impacts. Transportation projects should incorporate green design with added protection of landscape features that promote infiltration and slow runoff. Keeping a variety of transportation options viable will be important for interstate commerce as well as state and local emergency response to natural disasters.

Water Supply and Treatment – Protecting human health, especially during natural disasters, relies on both safe and adequate drinking water supply. Other water uses are essential to power generation for cooling water, industry, other domestic activities, agriculture and recreation. There is considerable built infrastructure associated with water supply, including dams to create storage impoundments, treatment facilities and distribution systems. Climate change can affect the availability and quality of water supplies (See Water Resources fact sheet) but also disrupt and damage the infrastructure necessary to treat and deliver water to domestic, industrial and agricultural users. In Connecticut, domestic water supply is of primary concern. Flooding can both physically damage infrastructure and contaminate the supplies from inundation with lower quality flood waters. Extended drought or flood can impact the supply and viability of groundwater as well. It is essential that the risk to these water supplies be further evaluated in light of climate change effects, and necessary adaptations, including alternative water supply during emergencies, be developed and implemented. Regional interconnections between public water supply systems and supply sharing can provide increased system reliability during these events. Also, because loss of power is likely during severe storm situations, alternative emergency power supplies are essential to continued treatment and pumping.

Wastewater Treatment – There are over 100 sewage treatment plants (STP) that discharge directly to the surface waters of Connecticut. Most STPs in Connecticut are publicly owned by municipalities and are the responsibility of local water pollution control authorities. By design, STPs are located close to receiving waters, at low points in the sewer service area so sewage can be cost-effectively gravity fed to the treatment facility without pumping. For that reason, the risks to these STP facilities from

flooding both along rivers or the coast can be high. In cases where supplemental pumping of the waste is needed, those pump stations are also often located at low points in the sewer system and can be at risk from river and coastal flooding.

Inundation of several Connecticut STPs during the 1984 flood events graphically illustrated some inadequacies in preparedness for high water. Municipalities consequently invested in flood proofing measures at their STPs. However, with more frequent flood events anticipated, it is unclear if those measures are protective enough.

Conversely, low flowing rivers can impact attenuation and waste load may not be adequately addressed in periods of relative dryness. Streamflow is an important consideration in wasteload allocation and evaluations are generally based on the lowest seven-day flow condition in a ten-year period. Creative reuse of wastewaters for cooling, industrial or irrigation purposes may alleviate demand, and receiving water impacts, during drought conditions. (See also the Water Resources fact sheet for more details on water quality and quantity climate change related discussion).

More careful consideration must be given to future climate and weather conditions to adequately protect existing infrastructure such as pump stations and wastewater treatment facilities. This includes locating and designing new infrastructure that meets future needs and standards for protection. Planning for climate change now, when communities invest in planned updating and upgrading of their existing facilities, would save money by protecting their investments from future damage. As with water supply treatment, alternative emergency power supply is essential, and must be planned for, during power outages.

Federal regulations currently require that treatment facilities be able to sustain the impact of a 25-year storm without damage and remain operational. These wastewater facilities must also be protected from damage in the case of a 100-year storm event although operation may be temporarily affected. However, reevaluation of the character of future 25-year and 100-year storm intensities is necessary if these standards are to be maintained and engineering and design practices upgraded accordingly. In Connecticut, protection against today's 100-year storm may provide a realistic level of protection although there should be an expectation that today's 100-year storm will occur more frequently in the future. Adaptation in the form of more frequent inspections after floods and repairs of flood proofing features may be an effective strategy to protect infrastructure from more frequent stress. Assessments of vulnerability of, and risk to, existing structures from projected increased frequencies of storm events should be a priority in Connecticut's adaptation strategy for pump stations and wastewater treatment facilities.

The Clean Water Fund (CWF) includes monies to upgrade wastewater treatment facilities and to expand their infrastructure. Connecticut's Environmental Policy Act (CEPA) requires evaluation of CWF wastewater treatment facility projects to consider indirect effects in the environmental impact evaluation prepared for each project. The broad indirect effects category should include climate related concerns such as flood proofing and locational issues associated with adaptation to climate change, and energy efficiency of these facilities, as part of climate change mitigation efforts.

In addition to wastewater treatment plant operations, changes in weather patterns may also affect sewer systems and wastewater loads to the STPs. Leaky sewers, direct inflow from storm drains and illegal homeowner sump pump and roof leader drain overflows, all stress sewer systems, especially older systems. It is imperative that combined sewer overflow (CSO) abatement projects are constructed with realistic standards in mind to address future higher flows. Several large municipalities are required to separate combined sewer systems to handle stormwater flow separately from sanitary sewage. Abatement strategies are designed to reduce the influent load on STPs and eliminate releases of raw sewage that are of concern in a few of Connecticut's large cities during storm events. If the same level of protection from CSO events that is being designed for today is to be maintained in the future under higher rainfall conditions, Connecticut and its municipalities will need to recalibrate planning models based upon newer data.

Both centralized (treating several residences) and individual subsurface sewage (septic) system efficacy may be affected by changes in weather patterns related to climate change. Effective subsurface treatment relies on adequate separation between infiltration trenches and groundwater. This can be affected by changes in water table levels or sea level rise if located in a coastal area. Presently, subsurface systems are designed with a minimum of 18 inches between the leach trenches and high ground water to protect the ground water and nearby surface waters from contamination. As hydrology changes occur, particularly in low lying shoreline communities, the rising water table may not allow for adequate soil treatment travel times to remove pollutants and protect surface and ground water quality. Increased septic system failures may occur that threaten both human and environmental health. The cost and difficulty of remediating failed subsurface systems can be very high. Future conditions need to be considered as new systems are permitted and installed and new standards and technologies are evaluated.

Dams – Of the 5,500 dams in Connecticut, 3,000 come under the Connecticut Department of Environmental Protection's (CTDEP's) direct jurisdiction. Presently, 239 Connecticut dams are classified as high hazard, i.e., those which could potentially cause loss of life and major damage to structures and highways if they fail; 264 are classified as significant hazard; and another 692 are classified as moderate hazard.

Connecticut is dotted with historic industrial and manufacturing sites that utilized dams for process water, cooling water and power. Many of these dams now retain contaminated sediments. If a dam with contaminated sediment behind it fails, the contaminated sediment will travel downstream and likely bury and destroy fish and benthic invertebrate habitat, as well as impact wetlands and the watercourse.

Not all dams in Connecticut today meet spillway design standards for safely passing flood flows. CTDEP generally utilizes the United States Army Corps of Engineers' spillway design criteria as a basis for the design of repairs and reconstruction for dams. Generally a high hazard dam must be designed to pass the probable maximum flood (PMF) – the runoff generated from the most severe meteorological and hydrologic conditions that are reasonably possible in the region, a significant hazard dam – a ½ PMF, and moderate and low hazard dams – a 100-year return frequency flood. The anticipated increase in the frequency of flooding means that Connecticut dams should be reassessed for their vulnerability and risk from additional flooding events in a changing climate.

In addition, regional climate change reports are anticipating more wet days and more extreme rainfall events. Thus climate changes such as the amount of rainfall, the variability of rainfall events, and the likelihood of extreme weather events, all emphasize the need for ensuring that dam owners keep their dams in good condition. If dams are not maintained in good condition then climate change factors which increase the stress on dams also increase the risk of those living downstream. Basically more extreme rainfall events lead to increased frequency of stress on dams, increasing the risk of dam failure.

If a high, significant or moderate hazard dam fails, there could be potentially catastrophic impacts on the built environment downstream as well as potential loss of life. The current conditions of regulated dams range from good to critical (unsafe). CTDEP has recently stepped-up efforts to assess state-owned dams and assign a priority to private and public dams for inspection and repair based on threats to public safety. As a consequence, more communities will be looking for financial and technical assistance to manage dams, especially as increased flooding is projected to further tax these structures, threaten public safety, and increase environmental risk. The best solution, in some cases to adapt to a changing climate as well as to generally improve environmental conditions, may be to remove some dams in an environmentally responsible manner.

In addition, climate change underscores the need for enhanced emergency planning for high and significant hazard dams in order to better protect those citizens living downstream in potential inundation zones. The Association of State Dam Safety Officials (ASDSO) recommends that states require dam owners to prepare an Emergency Operation Plan (EOP) for each high and significant hazard dam. Public safety is

greatly enhanced by having up-to-date EOPs in place and available for local and state emergency response personnel and dam safety officials. EOPs also must be updated periodically in order to maintain their usefulness.

Landscape "Infrastructure" – As related to some of the risk categories above, some types of infrastructure are incorporated into the landscape as "best management practices" (BMPs) to control stormwater and nonpoint source runoff quantity and quality, protecting both human water supply and natural resource needs. The BMPs often include preservation of natural features that promote infiltration and dampen runoff effects of rainfall. BMPs also are actively implemented through landscape modification that attempts to simulate natural land features. These can have substantial costs and be at risk from climate change impacts, especially storms and changes in hydrology including inundation. Some BMPs are true structures that treat runoff and are subject to the same damaging forces of nature that affect more visible infrastructure. Others, especially activities that preserve and promote natural features to infiltrate rainwater, slow runoff velocities, stabilize or protect erodible areas such as stream banks, or buffer against storm events in a manner similar to coastal wetlands or floodplains.

As infrastructure is constructed, added attention should be directed towards minimizing impervious surfaces and ensuring the types of landscape infrastructure, or BMPs, that are necessary to mitigate the effects of hardening of the landscape and altering drainage patterns that built infrastructure causes. (See effects of impervious cover in the Water Resources fact sheet). Types and sizing of BMPs, or changes in the capacity of watersheds to dampen the effects of those changes under a changed climate regime should be evaluated at the project level as well as in watershed planning exercises.

Effects may not always be as obvious as even subtle changes in vegetative cover can alter the hydrologic cycle by increasing evapotranspiration with more tree coverage, for example, which may further increase with climate change as growing periods become longer.

What Connecticut is Doing

Among CTDEP programs that can benefit infrastructure and landscape protection through adaptation now and under a changed climate regime are:

- Natural hazard mitigation planning and disaster response
- Stream channel encroachment and streamflow regulation
- Water planning and management
- Wastewater permitting and Clean Water Fund financing for STP upgrades
- Dam safety and management
- Coastal management programs
- Stormwater permitting
- Nonpoint source and watershed management planning
- Low impact development and landscape management practices

Natural Disaster Planning and Responses - Even with a concerted and effective effort to adapt to climate change, there is a high level of uncertainty in the process, and change is likely to be slow. Connecticut will undoubtedly be struck with natural disasters along the way and, coupled with the lack of a major storm event in several decades, at risk infrastructure has grown substantially. Also, natural features, especially the number of mature trees that may contribute to both infrastructure impacts as well as debris load will add to the damaging force of a major storm or fuel a fire.

Working cooperatively with the Department of Emergency Management and Homeland Security and other state agencies, CTDEP plays an important and continuing role in natural hazard mitigation planning and disaster response. Most recently, CTDEP completed disaster debris planning, including development of the state's *Disaster Debris Management Plan*, and debris removal and monitoring contracts. Proper planning for debris management is prudent to minimize impacts and speed recovery from a natural disaster such as flooding and significant storm events. Every community should have a debris management plan that should include a standing contract to remove material in the event of severe storm or flooding.

Plans should recognize the changes in the landscape since past major events, how more frequent and intense storm and drought patterns may affect Connecticut's infrastructure, and the task of cleaning up. Consideration should be given to prudent adaptive techniques that may involve tree removal or trimming to reduce damage to structures, transmission lines, transportation routes, and flood elevations and force. Similarly, regular inspection of streams, culverts and other drainage structures to assure that they are maintained clear of debris or obstructions is a preventive and mitigative measure.

Stream Channel Encroachment Regulation - In order to lessen the flooding hazards to life and property, the CTDEP regulates the placement of structures and obstructions riverward of stream channel encroachment lines. Stream channel encroachment lines have been established for about 270 linear miles of riverine floodplain throughout the state, and are shown on stream channel encroachment line maps, which are on file in the town clerk's office in affected towns.

Water Supply and Streamflow – CTDEP works in partnership with the Connecticut Department of Public Health who is responsible for assuring the purity and adequacy of drinking water supplies. CTDEP is also charged with protecting natural resources by ensuring that, in addition to meeting human needs for water, there is adequate flow left to maintain healthy ecosystems. This is a challenging proposition, to find or develop clean water sources where they are needed in Connecticut. (For additional variables impacting water resources see the Water Resources fact sheet).

In addition to the need for more foresight in planning for human needs in the face of changing weather patterns to ensure sustainable water supplies, CTDEP is developing streamflow regulations that are aimed at protecting natural resources in rivers and streams throughout the state. The success of these efforts will depend on Connecticut's ability to project future conditions of flood and drought under changed climate and incorporate these projections into development decision making. Innovative options for wastewater reuse, conservation, and wise stewardship of available water resources all need to be factored into these plans and regulations.

Wastewater Treatment Plant Planning - In February 2008, the CTDEP evaluated the impact of climate change on low-lying wastewater treatment plants and their tributary sewer systems. This effort is intended to facilitate informed decision-making about major repairs and reconstruction projects at STPs to avoid flooding and other damaging forces.

Monitoring State Dams During and After Flood Events - During fiscal year 2008, CTDEP undertook the first phase of developing a computer-based monitoring system, known as DAM WATCH, for CTDEP-owned high and significant hazard dams during flooding events. DAM WATCH evaluates stream flow, rainfall and other real time hydrologic data and then applies it to established criteria to determine which CTDEP dams are most in need of on the ground surveillance and inspection. DAM WATCH allows staff to respond to concerns by quickly evaluating and responding to flooding at various state-owned dams.

Coastal Management - CTDEP, through its federally-approved coastal management program, provides technical assistance and project review for coastal municipalities. Municipalities partner with CTDEP to implement Coastal Management Act policies, which include discouraging armored shorelines and minimizing exposure of people and property to coastal hazards. However, inherently embedded in this effort is the difficulty of reconciling these twin needs so that the reality of some inevitable armoring of the shoreline to protect existing assets does not defeat the environmental protection that is an obligation under the Coastal Management Act. While stewardship of the environment is the CTDEP's priority, it will be balanced within realistic financial means with the needs of society along Connecticut's coast.

To aid in the coastal analyses, CTDEP has a National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center Program fellow who is developing a coastal hazards website to provide information, including maps and data, to the public and government officials about coastal hazards. This

will include information about how climate change may modify these hazards. CTDEP is co-chairing the Coastal Hazards Committee of the Northeast Regional Ocean Council (NROC), a partnership of the six New England states and six federal agencies focused on ocean and coastal planning and management issues on a regional basis. One of the core themes of NROC's Action Plan is to "Render New England a Coastal Hazards Ready Region." The Coastal Hazards Committee has established a work plan and, as an initial activity, held a workshop to engage federal, state and local officials in a dialogue on regional coastal hazards and resiliency issues. A new flood risk assessment for coastal systems based on hydrologic patterns and projections of the 100-year floodplain under future climate scenarios is being developed at the federal level. This information will be used by Connecticut and its municipalities to inform land use decisions moving forward and may ultimately encourage development retreat from coastal areas that cannot sustain the built environment. Actions of other adjacent states, such as the potential armoring of New York State's East River, may need to be included as potential variables in Connecticut analyses of potential shoreline impacts.

Stormwater, nonpoint source, and landscape management – State and local plans can set the tone for land regulation practices that adapt to climate change. However, state and local adaptation will ultimately require careful crafting of stormwater permit features, watershed planning and management actions, preservation of natural features that promote infiltration and runoff control, and the newest technologies to mitigate the effects of climate change such as low impact development. CTDEP is working to adjust programs in all areas to meet those adaptive demands and help ensure Connecticut's management of the land does not exacerbate the effects of climate change. (See the Water Resources fact sheet for discussion on low impact development).

Related Programs and Activities

There are numerous plans and regulations at the federal, state and local level that will require collaborative programming efforts for areas of overlapping authority related to climate change. In particular:

- *Natural Hazards Mitigation Plan*
- *Conservation and Development Policies Plan for Connecticut* (POCD)
- Local land use zoning and regulation

The *Natural Hazards Mitigation Plan* - The 2007 – 2010 plan examines Connecticut's history and risk of natural disasters, evaluates Connecticut's geographic vulnerability, outlines which hazard mitigation measures merit the greatest priority, and identifies long-term measures to reduce losses from future natural disasters.

The *Conservation and Development Policies Plan for Connecticut* – Connecticut's five-year POCD developed within the Office of Policy and Management should set the tone for statewide adaptive actions as related to development patterns and infrastructure placement in the state. Due consideration to the changes in risk brought about by climate change from flooding, drought, and catastrophic storm events needs to be prominently addressed in the POCD and related to regional and local decisions throughout the state. Also, protection of landscape features that mitigate the effects of climate change need to be evaluated on a statewide basis, and afforded appropriate levels of protection.

Local Land Use and Zoning – Many of the authorities essential to climate change adaptation are managed at the local level by Planning and Zoning, Inland Wetland, and Conservation Commissions. Local officials need to be informed about the potential risks of climate change when updating their local plans of conservation and development to ensure planned development and infrastructure are protected from, and do not exacerbate, the effects of climate change.

Action is Needed Now

The time to plan and act is now. Adapting the natural and built environments for the inevitable changes needs to become a standard consideration as Connecticut plans and upgrades critical infrastructure components.

Flooding and its impact on Connecticut's infrastructure will test the fiscal limitations and organizational roles of the state and its municipalities. Now is the time to create resilient communities that can withstand the storms New England will face and an encroaching sea.

The CTDEP recognizes the need to implement sound flood plain management and natural hazards mitigation principles through technical guidance, model ordinances, education, and policies. The CTDEP will continue to look for opportunities to bolster the State's Dam Safety Program and continue to collaborate with other agencies and dam owners to enhance flood prevention and protection. The CTDEP will also continue to encourage local communities to become more proactive in terms of flood management and natural hazards mitigation, by encouraging the implementation of specific mitigation projects appropriate for a community's self-assessed hazards and risks. It is vital for local communities to prepare effective Natural Hazards Mitigation Plans and maintain them in a current status.

This is one of eight documents in the series *Facing our Future* concerning Connecticut's changing climate, www.ct.gov/dep/climatechange

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RESOURCE LINKS

- For nonpoint source education and planning see nemo.uconn.edu/
- For floods and other emergencies be prepared, see the Ready America link on the Connecticut Department of Emergency Management and Homeland Security website at www.ready.gov/america/makeaplan/index.html
- Use FEMA guidance and information on preparing for hazards, preventing disaster losses, applying mitigation best practices and undertaking community mitigation planning. Visit www.fema.gov
- For transportation infrastructure changes see www.ct.gov/dot/site/default.asp
- For the latest in environmental impact evaluations for water projects see www.ct.gov/dep/cwp/view.asp?a=2719&q=382742&depNav_GID=1654
- For the Connecticut Hazard Mitigation Plan see www.ct.gov/dep/lib/dep/water_inland/hazard_mitigation/plan/hazardmitigationplan.pdf
- For the Disaster Debris Management Plan and contracting information see http://www.ct.gov/dep/cwp/view.asp?a=2718&Q=410492&depNav_GID=1646
- For the National Oceanic and Atmospheric Administration see www.noaa.gov/about-noaa.html
- For recommendations for Revisions to Municipal Plans of Conservation and Development and/or Zoning and Subdivision Regulations see www.ct.gov/dep/cwp/view.asp?a=2705&q=323570&depNav_GID=1622
- For further details on the importance of buffers see clear.uconn.edu/projects/riparian_buffer/results/CLEAR_%20Summary_021508.pdf
- For Coastal Wastewater Infrastructure review *Potential Impacts of Global Warming on Connecticut's Wastewater Infrastructure*, a preliminary 2008 report by Krista Fisk with an introduction by Dennis Greci
- For Jordan Cove Urban Watershed Project see www.jordancove.uconn.edu/jordan_cove/publications/jordan_cove_brochure.pdf

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE:

Natural Coastal Shoreline Environment

Adapting to Connecticut's Changing Climate

"The biggest problem is that climate change and sea-level rise will come on top of the existing effects of habitat loss along the shore. Consequently, species that are already in a precarious state will have to deal with an additional set of problems. Ultimately, large-scale land use planning and better long-term monitoring of the state's biological diversity are the best ways to address all of these issues."

Sound Health 2008 'Wildlife & Habitats' Chris Elphick, PhD, Conservation Biologist, Department of Ecology & Evolutionary Biology, University of Connecticut

Coastal Implications

The region's largest estuary with an area of 1,320 square miles, Long Island Sound is home to more than 120 species of finfish and countless varieties of birds and other animals. Between New York and Connecticut, the Sound's coastline stretches more than 600 miles. Over the last three decades, Connecticut has made a significant commitment to protecting and restoring the Sound. Hundreds of millions of dollars have been invested to address pollution concerns and protect the tidal wetlands along its shore.

As climate change brings warming temperatures and intensified sea level rise to Connecticut's coastline we must begin to take action to protect the ecosystem. Along with other stressors the changing climate is impacting Connecticut's natural coastal environment in ways that may not support the continuation of current coastal habitats.

Sea Level Rise – Sea level rise projections vary but moderate estimates from a 2001 report by the Intergovernmental Panel on Climate Change state that global warming of 2.5° to 10.4° F (1.4°-5.8° C) could lead to a sea level rise of four inches to 2.9 feet by 2100. This does not take into consideration estimates incorporating the more dramatic melting of ice sheets that may already be occurring.

Shoreline Erosion - Accelerating sea level rise will mean that the average shoreline erosion rate, which in certain areas of Connecticut reaches one to three feet per year, will increase. Shoreline erosion could increase even more with the increased frequency and intensity of hurricanes and nor'easters that are anticipated. As a consequence, the terrestrial footprint of Connecticut decreases every year in response to sea level rise, a phenomenon that has been occurring for thousands of years but is now accelerating.

Barrier Beaches - Beaches with dunes, such as Long Beach in Stratford and Bushy Point Beach at Bluff Point in Groton, form barriers across water bodies creating sheltered lagoons and tidal wetlands. As sea level rises, storms wash the dunes into the lagoon, and the dunes rebuild and migrate landward. Under accelerated sea level rise, it is not known if these beaches will endure. These natural beaches contain rare plant communities and host endangered bird species like piping plovers. Endangered plovers nest on sandy beaches on open ground, a habitat that is being eliminated by these subtle and not so subtle changes in the coastline.

Further upland, existing coastal forests are experiencing the impacts of sea level rise. In Stonington at the edge of the Barn Island wetlands, a forest of black gum trees is being inundated more frequently by high tide events. Since these trees are not adapted to a high level of salt around their roots, their habitat is threatened. (Other forestry stressors are identified in the Forestry fact sheet).

Hypoxia – The severity of low dissolved oxygen (hypoxia) in the bottom waters of Long Island Sound is dependent on several factors not the least of which are seasonal temperature extremes. Changing weather patterns, including both warmer temperatures and shifting winds brought on by climate change, are important drivers. In Long Island Sound, nutrient loading, primarily in the form of nitrogen, stimulates algal growth. Climate change can exacerbate nutrient loading (see Water Resources Fact Sheet) and, combined with warmer water temperatures and wind changes, Connecticut has begun to see some effects. Excessive nutrient loading stimulates algal blooms and, when the algae and zooplankton settle into the darker, cooler bottom waters, their decomposition uses up the dissolved oxygen in the bottom waters, causing hypoxia.

During the summer, the strong temperature difference between surface and bottom waters causes stratification that prevents oxygenated surface water from circulating downward so that bottom-dwelling, oxygen-dependent organisms die or swim away to other waters where there is oxygen. Monitoring data suggests that warmer surface waters and shifts in wind patterns associated with climate change are strengthening stratification. While increased wind and rain events can remix the water to dissipate hypoxia, increased fresh water in the surface waters also exacerbates stratification by creating salinity density differences much as temperature does. These climate change effects may be altering the location and duration of hypoxia in Long Island Sound. If these trends continue, the benefits of nitrogen management efforts may be offset by the physical changes brought on by climate change, and water quality goals for hypoxia will not be met. (For the implications of a changing climate on fisheries see the Fisheries fact sheet).

Globally Significant Habitat - Barn Island is a unique location with five tidal marshes. Tidal wetlands are one of the most productive habitats on the globe, second only to rain forests. They developed several thousand years ago when sea level rise rates slowed to 1 mm/yr. Under the two millimeter rise of the past century, most persisted except for areas in western Long Island Sound where the lower elevation grasses have been converting to mudflat over several decades. Marshes can keep pace with sea level by accumulating sediment and building soil with roots but scientists do not know at what sea level rise rate marshes will drown. The highest forecasts of 15 mm/yr (0.6 in/yr) are very likely to cause marsh grass drowning making future tidal wetlands only narrow fringes. It is expected that there will also be a loss of plant diversity and regional genetic stock.

Example of wetland loss from submergence of the Quinnipiac River marsh in LIS. Wetland loss should increase with accelerated sea level rise.

Nowhere To Go - Tidal marshes grow vertically and move horizontally landward with rising sea level. However, in places where there are cliffs or developed lands (e.g., bulkheads and seawalls) the otherwise natural progression of the marsh toward the upland side becomes an impossible task. The marsh is essentially squeezed out of existence as the higher salt water drowns the seaward grasses and the land wall blocks the grasses on the landward side from moving inland. Losses of coastal wetlands reduce an important buffer against the impacts of storm surges, flooding and releases of pollutants from the land. (See the Infrastructure and Water Resources fact sheets for more details).

The freshwater and brackish tidal marshes of the Connecticut River were designated as Wetlands of International Importance in 1994. If the snowpack decreases in New England, and subsequently the spring freshet is reduced, and other precipitation patterns do not adjust to

subsidize this deficiency, salt water will move further upriver. Under this scenario, new brackish marshes will begin to replace freshwater tidal marshes.

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Vulnerable Species - Timing is critical for the saltmarsh sharp-tail sparrow that only nests in high parts of the high marsh in short grass. Its cycle of laying eggs, hatching and independence of hatchlings only takes 27 days. However, as hydrology shifts in the marsh it can disrupt this cycle causing eggs or hatchlings to be washed out of their nests. This bird species may be one of the more vulnerable to sea level rise in North America because a few inches of sea level rise results in a loss of their narrow band of breeding habitat.

Seaside sparrow, which only occurs in a few large marshes in Connecticut, is another coastal species dependent upon salt marsh habitats. The loss of these habitats due to sea-level rise is also expected to reduce the area of habitat available for feeding and cover. This change of reduced overall habitat area will particularly affect the seaside sparrow. (For more about habitats see the Biodiversity and Wildlife fact sheets).

Why Action is Needed Now

With accelerated sea level rise, in combination with other varied stressors, important natural links will be broken and others will form with unforeseen results. It is uncertain how quickly, if at all, species will be able to adapt to sea level rise in conjunction with all of the other variables such as direct human interference and encroaching invasive species. Because of these uncertainties it is incumbent upon Connecticut to protect existing habitats and make plans to minimize and hopefully reverse these projected changes to Connecticut's coastal environment.

Continued and new monitoring is needed to better quantify the impacts of climate change and evaluate the success of adaptation strategies. The Connecticut Department of Environmental Protection (CTDEP) and educational affiliates will need to conduct environmental monitoring to determine the success of preservation and restoration efforts relative to a baseline and whether or not the strategies need to be adjusted. Critical areas that warrant closer monitoring include sites like the Housatonic River, Nells Island and Barn Island, so predictions concerning the resilience of the natural coastal environment can be made in ways that inform us about necessary investments for long term ecological health.

To make our shoreline and its communities and habitats more resilient, existing conceptions of property rights and regulatory authorities must be reevaluated. New approaches must be considered in light of the need for tailored and thoughtful variation in response to rising sea levels and more frequent and intense storms. New or revised policies for establishing clear standards and encouraging sustainable and economically viable outcomes regarding shoreline armoring versus retreat, proactively protecting habitats and ensuring responsible growth are all part of what Connecticut needs to be doing as part of an adaptation strategy in the face of a changing climate. The CTDEP can lead by example through fully evaluating proactive measures, including the potential for retreat as an option to protect natural coastal habitats in state managed lands.

Hammonassett October 2008

What Connecticut is Doing

Information management - In 2008, the CTDEP partnered with the University of Connecticut Marine Sciences Program to begin the development of a monitoring strategy to assess how climate change will affect the coastal ecoregion and coastal waters of Connecticut. Ocean observing systems and sentinel monitoring sites are essential to accurate tracking of change and the development of effective adaptation plans. The EPA Long Island Sound Study supports climate change monitoring and provided Connecticut and New York with startup funds to further the development of a strategy and fund new monitoring. In partnership with the CTDEP, the United States Geological Survey and the University of Connecticut Marine Sciences Program, funding was received from the Long Island Sound Fund to install, maintain and operate real-time recording salinity gauges on the Connecticut River to evaluate the upstream migration of the salt water wedge and the consequences for the river's wetlands, designated as Wetlands of International Importance. This continues the CTDEP's collaborative administrative stewardship of long term monitoring projects to ensure, into the future, continuity over the continuum of researchers from various educational and environmental organizations.

The CTDEP has recently acquired high resolution elevation data for the coastal hazard zone of the coast that could assist with the production of inundation scenarios based on sea level rise projections. These data could also be helpful in identifying low-lying lands along the coast that could sustain tidal wetlands in the future.

The CTDEP has created historic shoreline information in GIS that can be used with modern shoreline maps being generated by the National Oceanic and Atmospheric Administration (NOAA) to calculate rates of shoreline erosion.

Education – As published in the *Sound Outlook* (June 2008), Connecticut Sea Grant, with the support of the CTDEP, recently received a grant to raise public awareness of the significance of the Connecticut River estuary and tidal wetlands complex as it relates to the 1994 designation of Ramsar Wetlands of International Importance and to World Wetlands Day. Connecticut recognizes the need to identify the most vulnerable habitat types, and living resources, and closely monitor and examine climate change scenarios to devise adaptation responses.

In Conclusion - Future climate change impacts to Connecticut's treasured coastline could be substantial. To help mitigate these impacts the CTDEP will: continue to protect state managed coastal lands, monitor changes in ecological indicators, and seek proactive options to protect coastal habitats in a way that fosters adaptation to changing climatic conditions.

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IMPROVEMENTS AND CHALLENGES FOR TODAY

Individual, Corporate, Municipal and State Stewardship

- Review rights and opportunities in shoreline development, see the CTDEP's web site at www.ct.gov/dep/cwp/view.asp?a=2705&q=323542&depNav_GID=1622&depNav=|
- Eliminate the use of fertilizers, pesticides and herbicides in coastal communities to help mitigate the effects of hypoxia.
- Assess estuary vulnerability, see EPA's Climate Ready Estuaries program.
- Review Rhode Island Sea Grant website, including a national summary of responses to sea level rise by state, seagrant.gso.uri.edu/ccd/haz.html
- Utilize updated USGS saltwater intrusion mapping for Connecticut, once available.
- Monitor sea level rise relative to elevation to better understand the impacts on wetlands.
- Identify areas adjacent to Connecticut's major tidal marshes capable of accommodating the inland migration of marshes as sea-levels rise and, where appropriate, acquire these areas for conservation purposes.
- Consider possible adaptation strategies including utilizing seed banks.
- Employ beneficial use of dredged material for artificial high marsh.
- Continue to work with the Coastal Hazards Standing Committee of the Northeast Regional Ocean Council to acquire the data and tools that are needed for hazards planning and sea level rise adaptation.

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE: Outdoor Recreation Adapting to Connecticut's Changing Climate

"Residents and out-of-state visitors enjoy some 8 million recreation days each year in Connecticut's 171,479 acres of state parks and state forests, generating $2.4 million in day-use fees. Our state's public and private campgrounds attract over 900,000 visitors each year, generating $16 million in user fees. Campground travelers (about 38% are out-of-state visitors) spend some $296 million in our state each year."

The Connecticut Statewide Forest Resource Plan 2004-2013

Implications of a Changing Climate on Outdoor Recreation

The changing climate in Connecticut is impacting when and how residents and tourists will enjoy the outdoors. Traditional winter sports will be at risk when the state no longer experiences the depth of ice and longer seasonal snow cover that it once did to support snowmobiling, skiing, skating and ice fishing. Hotter weather will drive more people from our cities to the shore for relief. Greater demand at our shoreline beaches is coming when these same beaches are being eroded away at an accelerated rate. Hikers seeking solace in Connecticut's beautiful open spaces will need to use more caution to avoid Lyme disease from ticks, West Nile from mosquitoes, and greater exposure to the sun. Yet, getting outside will remain essential to a sense of well being.

According to the *Connecticut Statewide Comprehensive Outdoor Recreation Plan* (2005-2010), the State of Connecticut and its 169 municipalities are the dominant providers of outdoor recreational opportunities in Connecticut. The Connecticut Department of Environmental Protection (CTDEP) owns 66% of the total recreational acreage, with municipalities owning 17% and other entities owning the remaining 17%. The CTDEP provides major shares of the natural resource based supply of recreation, including 70.5% of hunting activity and 25-33% of boating access, camping, fishing, and winter sports facilities. Municipalities provide most of the playgrounds, athletic fields and swimming pools. Private clubs and organizations own the majority of golf courses, and provide 25% or more of volleyball facilities, beaches, boating access, swimming pools, camp sites, and hunting and fishing access areas. A few activities such as hunting, fishing, boating, trails, and historic sites receive significant levels of support from all three sources: state, municipal, and private ownership.

Despite, or in some cases because of, the changing climate Connecticut citizens will continue to look to the outdoors to recreate as part of a healthy lifestyle and to appreciate nature's unique attributes. Connecticut's State Park and Forest system will need to be managed in a way that accounts for these increased demands at the same time the impacts of a changing climate alter the physical nature of these parks. Short term responses necessary to maintain viable recreation activities will need to be balanced with long term planning that accounts for rising sea level, increased frequency and severity of flooding, drought, and eroding shorelines. (See also the Natural Coastal, Forestry and Wildlife fact sheets for additional factors that need to be taken into consideration as part of the long term planning efforts).

Summer Activities - Projections by the Union of Concerned Scientists say there will be at least 30 or more days with temperatures over 90°F in the northeast by 2040. Hotter weather will begin sooner and last longer. The first heat wave of the summer of 2008 hit Connecticut in early June. Temperatures in the state peaked above 90°F four days in a row. The maximum daily temperature recorded at Bradley Airport during this heat wave was 98°F. On all four days the CTDEP issued Air Quality Alerts for the public and regulated community under the new ozone standard. On June 10th air quality reached "Unhealthy" levels in some portions of the state, with the highest 8-hour ozone level measured in Greenwich. These higher ozone levels may trigger asthma and other respiratory ailments. Associated air quality alerts recommend that those susceptible to respiratory problems refrain from activities involving exertion outside. At the same time others will seek relief from this extreme heat at our shoreline and other parks that offer opportunities for swimming.

Beachgoers - Hammonassett is a very popular, heavily used state park serving more than 1.8 million visitors each year. Along with the other two major shoreline parks, Rocky Neck and Sherwood Island, these three parks host more than 40% of our park visitors each year. As summers become warmer there may be increased demand for beach access. While this is likely to result in increased revenues these revenues are not likely to keep up with the increased demands.

Today existing boardwalks at Hammonassett are under threat from advancing beach erosion and CTDEP is taking significant steps to temporarily stem this tide. As sea level rises and storm surges increase in intensity and frequency, long term solutions must be worked out. Boardwalks may need to be moved further inland reducing parking lots that are adjacent to the beach facilities. The majority of current parking and access for campers could be compromised. Beach related facilities may have to be removed or relocated. The redesign of these shoreline parks will need to consider components of retreat as one option, as the shoreline inevitability moves inland. Right now replenishing the beach annually with more sand is still the optimal position for Connecticut, but in short order the CTDEP will have to turn to more permanent solutions. Educating the visiting public to the threats of heat stress, sunlight exposure and natural hazards such as lightening and severe weather events will be important to ensuring the safety and health of future park visitors.

Boating – While projections point to more frequent and intense storm events, overall summer time precipitation is not expected to increase. However, with rising temperatures and increased evaporation rates, short-term drought conditions are expected to be more frequent. Coupled with ever increasing demands on the state's water resources, freshwater paddle sports such as canoeing and kayaking could be impacted.


Hammonassett October 2008

Fishing - Fishing is undergoing many changes due to changes in water temperature and other stresses on our fisheries. Cold water populations are losing ground in Connecticut freshwater and are being replaced by cool and warm water species. Impacts on recreational fishing and lobstering in Long Island Sound are expected as well. (For a much more in depth discussion on the changing climate and fisheries see the Fisheries factsheet).

Camping and Hiking –Flash floods can leave trails washed out or blocked with debris. The CTDEP may be forced to close certain trails and parks due to weather related damage. Heat stress will make some activities less enjoyable, and unsafe for some populations. Tick and mosquito seasons are expanding and will present additional public health challenges.

Winter Activities - Communities that rely on natural snow and ice for recreation are going to have to transition to shorter and shorter seasons and adjust to lack of in-season reliability. Opportunities to enjoy simple pleasures like sledding or playing pond hockey on a cold winter day are becoming harder and harder to find. Skiing at Mohawk Mountain, a winter playground in Connecticut for sixty years, may become less and less viable over the course of the next decade.

Ice fisherman and snowmobilers are impacted by ice depth and strength and ice-in and ice-out dates also reflect a shorter winter season than the recent past. In 2008, the CTDEP had to cancel its ice fishing derby for lack of reliable thick ice on Coventry (Wangunbaug) Lake.

What Connecticut is Doing

Camping - Camping at some state parks, is being extended at one or both ends of the season to meet demands for expanding spring and fall activities. CTDEP is continuing to develop additional campground capacity where it can be done cost effectively. In response to public demand and preferences, State Park Campgrounds will be offering cabins, electrical and utility hookups and WiFi to meet public expectations.

Trails – An emphasis has been placed on improving interconnectivity of state and local trail systems increasing opportunities for access between urban and suburban areas and our parks. Trails continue to be expanded and more emphasis is being placed on additional uses such as biking, letter boxing and geocaching.

Fishing - The CTDEP is stocking warm water and cool water fish in areas that can no longer sustain cold water species. In areas where cold water species are resistant and can thrive they will continue to be stocked. The Connecticut Aquatic Resources Education (CARE) workshops foster resource stewardship, promote an understanding of aquatic systems and utilization of aquatic resources. Additionally, *City Fishing* summer events have taught 25,000 minority youth on urban waters.

Sherwood Island is reducing impervious surfaces and improving stormwater quality by installing a stone dust parking lot and ditches to catch the first, most critical, hour of run-off. This allows precipitation to infiltrate, attenuating the impacts of stormwater on the natural environment. CTDEP needs to continue to look for opportunities to lead by example in promoting low impact development and green building practices at its facilities. (See the Water Resources and Infrastructure fact sheets for more details on low impact development and responsible growth).

Beachgoers - Increasing access to Long Island Sound will help distribute the demand placed on the shoreline parks. A public beach and boardwalk has been developed at Silver Sands in Milford and a master plan has been completed outlining further opportunities for expansion of facilities.

CT DEP will be monitoring the reduction in parking spaces at shoreline parks and increased demand. At some point Connecticut's shoreline parks could benefit from improved service by mass transit systems. In addition, greater capacity and facilities to accommodate multiple use trails to serve walkers and bikers, who will frequent the parks using alternative forms of transportation, will be important.

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RESOURCE LINKS

- Check for a state swimming area water quality report before heading to the beach at 1-866-287-2757 or check the website at www.ct.gov/dep/cwp/view.asp?a=2222&q=320786&depNav_GID=1654
- Check the air quality forecast at www.ct.gov/dep/cwp/view.asp?a=2222&q=320646&depNav_GID=1744
- Use shoreline pump-out facilities, before boating visit the DEP pump-out website at www.ct.gov/dep/cwp/view.asp?a=2705&q=323708&depNav_GID=1635
- Check for CARE classes across the state www.ct.gov/dep/cwp/view.asp?a=2696&q=386682&depNav_GID=1630
- Be prepared for extreme weather: see the Ready America link on the Connecticut Department of Emergency Management and Homeland Security website at www.ready.gov/america/makeaplan/index.html

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE:
Water Resources, Quality and Quantity
Adapting to Connecticut's Changing Climate

"Without set asides for the environment, streams, rivers, lakes, and other water bodies may suffer impairment and degradation during sustained periods of low flow. There may not be enough water to support fisheries and the aquatic life on which they depend, wildlife, and all of the other aspects of the natural environment which are water-dependent, as well as the recreational resources and natural beauty that make Connecticut so attractive to its residents and visitors. With careful planning, however, Connecticut can meet the needs of its citizens without sacrificing the quality of its natural environment." *Report to the General Assembly on State Water Allocation Policies Pursuant to Public Act 98-224,* January 2000.

Implications For Water Quality and Quantity

Connecticut is rich in natural water resources and fortunate to be located in a region of North America with a temperate climate. "The state has approximately 5,800 miles of rivers and streams, virtually all of which eventually flow to Long Island Sound. There are more than 2,300 lakes, ponds and reservoirs, and roughly 15% of Connecticut's land surface is composed of inland and tidal wetlands."[1] Unfortunately the existence of a connection between people and this varied land is not as obvious in today's Connecticut as it once was. Still, over 3.4 million residents depend on Connecticut's land and water resources for water supply, sewage disposal, living and work space, flood safety, farm products, and other socio-economic benefits. All of these uses and needs, without proper management, can impair water quality and availability in Connecticut.

While the state has made great strides in improving the quality of surface water and ground water in the past three decades, continued vigilance and innovation is needed to ensure protection of these irreplaceable resources. The impact of global warming and regional climate change can further tax Connecticut's freshwater resources and its watersheds, by both periodic flooding and drought, along with warming temperatures.

Water availability for ground and surface water systems is a complex function of numerous factors including: precipitation, temperature, evaporation from land and the surface of water bodies, transpiration by plants, runoff across the land surface, water withdrawals for human use, and human uses of the land including infrastructure (see the Infrastructure fact sheet). All of these factors are likely to be influenced by a changing climate. Today, Connecticut's average annual precipitation is approximately 47 inches, and is fairly evenly distributed throughout the year. Some of the annual precipitation is returned to the atmosphere through evaporation and transpiration, while the rest either runs off into streams and lakes or enters the groundwater system. How we use the land and water can greatly alter the water budget, and climate change projections for the future indicate precipitation will be more varied and extreme.

[1] *Report to the General Assembly on State Water Allocation Policies Pursuant to Public Act 98-224*, January 2000.

Increase in Frequency - The frequency of winter precipitation is projected to increase by 20 to 30 percent with more falling as rain than snow. The frequency of heavy damaging rainfall is expected to increase. By late century with warmer temperatures and lower precipitation in summer, drought, which already does occur in Connecticut, is projected to increase in frequency.[2] Connecticut is considered a relatively water-rich state. However, there are already existing conditions and stressors on water resources such as storm water, urban and suburban development, flooding, consumptive uses of water, and even drought. These interrelated variables need to be considered as Connecticut adapts to a changing climate by implementing low impact development, correcting existing poor land-use decision-making, and improving stewardship of water resources.

Stormwater - Stormwater-related events such as flooding can expand floodplains, increase variability of stream flows, increase water velocity and increase erosion. More frequent stormwater-related events are projected with a changing climate and in urban areas with combined sewers this is expected to increase the frequency of sewage overflows. These impacts can adversely affect water quality and aquatic ecosystem health. Erosion and sedimentation can cause significant impacts on coastal areas, wetlands, ponds, lakes, and streams. Nutrient loaded sediments containing phosphorous and nitrogen may settle in impoundments and be resuspended into the water column by storms leading to algal blooms. More frequent and intense storms can cause more frequent "turn over" in lakes and ponds making the normal spring/fall turn over less predictable. Similarly, warming temperatures may strengthen and extend periods of stratification in lakes, ponds and Long Island Sound, exacerbating low oxygen conditions and disrupting natural production cycles.

[2] Connecticut Summary from the Union of Concerned Scientists based on *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions*, a report of the Northeast Climate Impacts Assessment (NECIA, 2007).

Urban and Suburban Development – On undisturbed landscapes much of the precipitation naturally infiltrates into the soil. Natural flood attenuation is being lost in our urban and suburban landscapes where there is a growing amount of impervious surface such as concrete and asphalt. This can contribute to eutrophication and related low oxygen content of waters as loads of nutrients and biodegradable organic materials are increased. Eutrophic waters are inhospitable to many valued forms of aquatic life and as water quality degrades from over production.

Increased precipitation means higher levels of runoff contributing to floods and pollutant delivery from impervious surfaces. Warmer temperatures for longer periods can heat impervious surfaces and the stormwater that flows across them, delivering that heat to the streams and estuaries where it is discharged.

If developed areas are at greater risk from flooding from projected climate conditions, real property losses may increase. New low impact development (LID) practices that address both water quality and quantity concerns under current conditions as well as under a changed climate regime can partially offset impervious cover. Continued protection of floodplains and stream buffers is an important feature of a comprehensive LID strategy to protect the environment and property today and under future conditions. For example, keeping flood plains undeveloped but available to farming provides for an economic benefit while precluding a risk to development that may exacerbate flooding. This allows fields to be rejuvenated with nutrients naturally when flooded while providing a buffer from the negative effects of seasonal floodwaters on constructed property. Likewise, inland wetlands can provide a passive location for floodwaters. Past inland wetland losses have destroyed important habitats as well as the water quality benefits they provide. Protection and restoration of inland wetlands will help revive these lost functions as well as being an important adaptation strategy in Connecticut's changing climate.

Flooding - Flooding is Connecticut's most frequent and closely watched natural hazard. Changes in climate may increase that frequency.

Recently, the Five Mile River area of Darien, New Canaan, and Norwalk experienced three flood events that were at or above the 25-year flood event. In addition to property damage, more frequent flood events can alter the shape of watercourse channels, redefining channel dimensions that destroy habitat as well as flood mitigation capacity.

Flooding in water courses in low-lying coastal areas is further influenced by the effects of marine tides and storm surges. Potential for increased frequency of flooding in these historically heavily developed areas adds an additional challenge to the revitalization of brownfield sites. Flooding must be factored into both considerations of remediation and ultimate end use. (See the Infrastructure fact sheet for other effects of flooding in Connecticut).

Rising sea levels can cause saltwater intrusion of coastal aquifers. The 1938 Hurricane surge, for example, introduced salt water into the Groton reservoir. Sea level rise combined with the projected stronger storms, like the '38 hurricane, may further threaten these and other water supplies in the future. (Additional coastal implications are identified in the Infrastructure and Natural Coastal fact sheets).

With the possibility of more frequent flooding, maintenance of buffer zones will become more significant to both flood mitigation, as well as to preserving water quality and quantity. That protection may come in varied and non-traditional forms that may require relocation, reallocation and creativity as part of Connecticut's adaptive strategy.

Drought – In addition to more intense storms and related flooding, more frequent or longer dry spells are also projected in many climate change scenarios. Changes in depth and duration of snow pack, and reductions in infiltration capacity may ultimately alter recharge of groundwater, which affects water supplies. Poor land use decisions, including increases in impervious cover and higher peak runoff contributing to groundwater not being recharged, could have long term water resource ramifications.

Connecticut River Valley

Agricultural crops, will be impacted by Connecticut's changing climate, and in turn will impact stream flow. New crop varieties may be required to maintain productivity and meet future demands. These crops may have different water needs and timing that could stress aquatic life and water quality as it impacts stream flow.

Connecticut is beginning to see more frequent drought impacts, as shallower wells along some lakes dried up in the summer of 2007 and river flows sometimes fall below levels that protect habitat and the resource. Climate change is projected to increase periodic droughts. New England is overdue for a severe and prolonged drought. Conservation measures and reuse of wastewater effluent for cooling, irrigation and industrial purposes, are an essential part of Connecticut's adaptation strategy. Existing drought management measures will be continually re-evaluated to assure applicability to variability of extreme dryness.

Water Supply - Consumptive uses of water involve the withdrawal or diversion of water from a groundwater or surface water source for drinking, cooking, sanitation, irrigation for agriculture, lawns and golf courses, evaporative cooling, and industrial processes. "There are 151 public water supply reservoirs and roughly 6,600 public water supply wells in Connecticut. Reservoirs provide the majority of public water, serving an estimated 70% of the population. Public water supply wells serve an estimated 14% of the people. The remaining 16% of Connecticut residents use an estimated 250,000 privately owned wells for their water supply."[3]

[3] *Report to the General Assembly on State Water Allocation Policies Pursuant to Public Act 98-224*, January 2000, page 9.

Water supply is a multi-agency concern. For its part, the Connecticut Department of Environmental Protection (CTDEP) needs to enhance oversight of its water resource regulatory programs such as water diversion permitting and streamflow regulation, to verify that current hydrological stressors, projected climate change and the impact on the natural environment and infrastructure are all being taken into account. Other agencies will need to act accordingly.

Action is Needed Now

The key to protecting Connecticut's aquatic ecosystems and habitats is ensuring adequate water quantities, which directly relates to the quality of water resources. Climate change presents additional challenges as Connecticut's existing laws and policies concerning water allocation and water quality management must be harmonized to effectively plan for future needs while balancing ecological sustainability.

Water allocation is a key component of an adaptive management strategy to ensure a sustainable water supply in a changing environment. Protection of stream habitat and streamflows must consider not only the minimum flows that protect aquatic life, but also the range of flows along the hydrograph that are needed to support spawning, migration and other ecosystem life cycle considerations (See the Biodiversity fact sheet for more information). Continued and additional monitoring and management of water withdrawals and diversions are essential to effective management of streamflow conditions today and in a changing climate.

As Connecticut develops its adaptation strategies for watersheds it is essential to preserve areas now that are not impacted by anthropogenic (human) sources. Reference conditions will also allow comparisons between natural systems' responses to change with those impacted by human activity. Large forested watersheds, for example, provide a unique portfolio, and warrant protection. Among these are the Eight Mile and Salmon Rivers, and portions of the Housatonic River. (See the Forestry and Fisheries fact sheets for additional implications).

Efforts to promote responsible growth and best management practices such as LID help attenuate water quality and quantity impacts. LID measures are a critical tool now more instrumental in Connecticut's ability to adapt to a changing climate.

What Connecticut is Doing

The CTDEP supports a watershed by watershed approach for in-stream flow assessment specific to Connecticut basins. These assessments will be maintained within a watershed atlas to assist diversion applicants and resource managers with in-stream flow target-setting and regulation.

The CTDEP is promoting water supply sharing, flood skimming and reservoir expansion to more comprehensively address periods of drought and control downstream overflows. In addition, the CTDEP recommends development of Class B water resources and treated wastewater reuse for non-potable purposes such as industrial supply, cooling water, process water, irrigation, etc.
The CTDEP supports a cooperative program with the United States Geological Survey for monitoring of stream flow and water quality. These actions are critical to support Connecticut's efforts to anticipate and address future impacts adaptively. Other, future considerations include evaluation of modifications to the water diversion program, including implementation of core water conservation measures prior to approving an additional allocation of water through a diversion permit application.

Collaboration in New Development - The Jordan Cove Project highlights many design and construction choices made to reduce stormwater runoff from impervious surfaces and increase onsite groundwater infiltration. With funding from the federal Clean Water Act Section 319 Nonpoint Source Grant Program, this project drew together several partners, including the land owner/developer, local public works and public safety departments, CTDEP, the federal EPA, private environmental consultants and contractors. The project demonstrated the effectiveness of several collaborative LID management practices in maintaining pre-development runoff levels, which will provide a useful adaptive technique for changing climate conditions.

Reduction in Impervious Cover in Preexisting Developed Area - As discussed above, the relationship between impervious cover and water quantity and quality issues is providing an analytical framework to define solutions to today's problems as well as to adaptively prepare for conditions projected in a changing climate. (see CTDEP web site at www.ct.gov/dep/lib/dep/water/tmdl/tmdl_final/eaglevillefinal.pdf) To put this tool to use, the CTDEP has developed a management support document for Total Maximum Daily Load (TMDL) analyses that identifies the relationship of impervious cover and macroinvertebrates in Connecticut streams. There is a strong correlation between pollutant loads, stormwater flows, and runoff from impervious land cover within a watershed. Using this understanding, the Eagleville Brook in Mansfield, Connecticut TMDL set a percent reduction in effective impervious cover compared to current conditions.

The implementation of best management practices (BMPs) are expected to reduce the effect of impervious cover to a level that protects the aquatic biota living in the stream. The CTDEP will continue to work with watershed partners, including the Town of Mansfield, University of Connecticut, and conservation organizations to implement better stormwater management in the Eagleville Brook watershed. This will also provide adaptive benefits for future conditions of flood, drought and heat that may come with a changing climate.

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STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

FACING OUR FUTURE: Wildlife Adapting to Connecticut's Changing Climate

"It is not the strongest of the species that survive, not the most intelligent, but the most responsive to change." Charles Darwin (1853)

Implications for Wildlife

Though small in area (5,544 sq. miles), Connecticut hosts an incredible diversity of wildlife due to the variety of habitats it contains from the coastal plain and Long Island Sound in the south to the northwest hills. According to the Connecticut's *Comprehensive Wildlife Conservation Strategy* (CWCS) dated October 1, 2005, there are 84 species of mammals, 335 species of birds, 49 species of reptiles and amphibians, 168 species of fish, and an estimated 20,000 species of invertebrates living in the state. Some of these species, particularly "generalists" with adaptable habitat requirements are flourishing. Others, with very specific habitat requirements or existing on borders of their geographic range, are listed as endangered, threatened, or of special concern and their future existence in Connecticut is in jeopardy.

The accelerated rate of climate change will have a direct impact on habitats and the wildlife that depend upon them. Rising sea level will impact coastal wetlands and the balance between fresh and salt water in estuarine systems. More frequent and extreme occurrences of droughts and floods will impact the quantity, quality and condition of freshwater habitats. The composition of the forest will change as the northward progression of tree species accelerates. These changes will alter the suitability of habitats for specific species of wildlife over time. Simplistically, Connecticut can anticipate that some species will adapt to shifts in their habitat by shifting their ranges upward in elevation, northward or inland. However, this is less likely to occur if the changes are sudden or if there are obstacles to such migrations resulting in disconnected habitats. (Additional habitat related implications are discussed in the Biodiversity factsheet).

The CWCS identifies a number of threats to those wildlife species in greatest need of conservation. These include habitat loss and fragmentation, introduction of exotic invasive plants and animals, and habitat degradation. It is important to note that the impacts of climate change should not overshadow these other stressors. In fact, if the Connecticut Department of Environmental Protection (CTDEP) can effectively address some of these other threats, wildlife may be better able to adapt to the changing climate.

Birds - Connecticut's avifauna is dynamic. In general, over the past century, southern species such as cardinals and mockingbirds have extended their range northward. As temperatures warm at a greater rate, some bird species will benefit from milder winters and extended breeding seasons. Others, such as northern birds associated with forest habitats, will likely decline in Connecticut. Increased frequency of droughts and extreme storm events may inflict higher mortality during the breeding seasons.

Migratory birds, in particular, are vulnerable to the timing of food availability throughout their entire migration route. (Phenological implications are elaborated on in the Biodiversity fact sheet). In brief, synchronies between time of arrival and food supplies could

be disrupted by phenological changes and the consequences could be sudden and severe. Most insectivorous birds synchronize their nesting to coincide with invertebrate emergence. Changes in spring and fall temperatures may cause a shift in this synchrony, resulting in nest failure. Also, increased droughts in the Midwest prairie pothole region (the continent's "duck factory") and the inundation of coastal wintering marshes in the Southeastern United States could dramatically reduce waterfowl numbers.

To sustain viable populations throughout the progression of climate change, it will be necessary to maintain enough quality habitat over time. This is literally a moving target that will require bridging current habitats to future locations. For example, rising sea level along the Connecticut coast could jeopardize the saltmarsh sharptailed sparrow. Connecticut has the largest percentage of the world's population of this species and sea level rise will increase the risk of nest flooding. In order to sustain breeding populations of these sparrows, coastal buffers must be established to facilitate an inland expansion of coastal wetlands where this species occurs. (Coastal habitats are discussed further in the Natural Coastal fact sheet).

Saltmarsh sharptailed sparrow

Mammals - Connecticut's mammals range in size from the least shrew to the moose and in adaptability from the generalists to the specialists. As a rule, the larger more adaptable species will benefit from climate change while the smaller specialists may decline. Because mammals are not as mobile as birds, it is extremely important that their habitats be linked to allow for genetic diversity. Small populations existing in isolated patches of habitat are less likely to survive climate change than larger populations in large blocks of interconnected habitat. This can vary by species, even within the same genus. For example, the eastern cottontail is an introduced species of rabbit that occurs statewide in a wide variety of habitats. Its relative, the native New England cottontail, appears to have much more rigid habitat requirements and occurs only in localized areas. Should their localized habitats become unsuitable due to climate change, the New England cottontail would require replacement habitat and a way to get there in order to survive. The strategy for maintaining this species includes managing existing habitat, planning for future habitat, and ensuring that the two are connected.

Smaller mammals have limited home ranges, making them more vulnerable to the effects of climate change and habitat loss. They are unable to move long distances when local conditions deteriorate. Climate change may cause local conditions to degrade through drought, pollution, and hydrological changes. For example, water shrews feed on aquatic invertebrates found in streams. Hydrological changes could diminish local food availability and consequently reduce this species' distribution. Preservation of high quality corridors could mitigate these impacts.

The white-tailed deer is an example of a mammal that would likely benefit from a warming climate since a decline in winter severity would increase its survival. It is imperative that management systems be in place to maintain populations at levels that are consistent with the ecological carrying capacity. Overabundant deer populations can have devastating impacts on native vegetation, small mammals, and ground and shrub nesting birds. They can inhibit the forest's ability to regenerate and create opportunities for invasive plants to

colonize and overtake an ecosystem. In the case of deer, regulated hunting seasons are the only practical method of balancing populations of this species with ecological tolerances.


Overabundant deer, ©Paul J. Fusco All Rights Reserved

The potential for climate change to affect bats is unknown; however their winter survival could be threatened. Climate changes that affect the abundance and availability of night-flying insects could impact bats by reducing their food supply or impacting their ability to store fat reserves prior to hibernation. Additionally, warmer weather may delay the onset of hibernation disrupting a delicate bioenergetic balance. Suboptimal body conditions coupled with even minor changes in the temperature and humidity of their hibernacula could create excessive stressors at hibernation sites leading to low winter survival.

Reptiles and Amphibians - Reptiles and amphibians are often grouped together, but comprise a variety of species that use a diversity of wetland and terrestrial habitats. Amphibians are very closely associated with water resources, whereas reptiles are typically more mobile and some are better able to tolerate drought conditions. Reptiles and amphibians tend to be very sensitive to subtle environmental changes. Potentially, as temperatures warm with climate change, the availability of water and the quality of aquatic habitats will become more variable. Species associated with ephemeral aquatic habitats, like vernal pools, may be particularly vulnerable to altered precipitation patterns. Water resources may dry up before the larvae have metamorphosed into adults, causing lower rates of survival for these species.

Protection of core habitats, such as vernal pools and their upland buffers, is critical to reptiles and amphibians because of their limited capacity to migrate to new locations once their preferred habitat has been degraded. Climate change may result in local extinctions for some species if the hydrologic regime is significantly altered or if wetland buffers are not protected. (Water quality and quantity implications are discussed in the Water Resources fact sheet).


spotted salamander

Invertebrates - The invertebrate fauna of Connecticut is incredibly diverse; it is estimated that more than 20,000 species occur here. Taxa include; freshwater mussels, gastropods, dragonflies and damselflies, butterflies and moths, benthic marine mollusks, crustaceans, and numerous others. Many of these are rare and 170 species are state-listed as endangered, threatened or species of special concern in Connecticut.

Invertebrates are inextricably linked to their habitat and because of this, are excellent indicators of habitat health and quality. Native pollinators, like solitary bees, flower flies, and butterflies, feed on the nectar of wildflowers. Flowering, on average, is occurring earlier. As a result, the synchrony between plants and their pollinators may be changing. If the plants and the pollinators respond differently to climate change, the disruption of synchrony could have far-reaching impacts, extending to our own food supply. These synergies of factors, or multiple stressors, are causing tipping points in species' populations and life histories that cannot be recovered from.

As a group, freshwater mussels have declined historically due to physical alterations of their

habitat caused by dam construction and stream channelization. They are also susceptible to diminished water quality. Droughts and irregular precipitation patterns associated with the changing climate may exacerbate these conditions. Mitigating the existing threats by reducing non-point source pollution and restoring functional riparian buffers could help to alleviate the long-term effects of climate change on freshwater mussels.

Introduced insect pests have done incalculable damage to New England's ecosystems over the past century. Some of these, such as the wooly adelgid, are periodically reduced by extremely cold winter temperatures. As winters become warmer, the climatic controls on these exotic invasives may be reduced allowing them to expand their range and their impact.

There is evidence that some mosquito species are expanding their range in response to climate fluctuations. In the last decade, two exotic species of mosquito have been indentified in Connecticut: the Asian tiger mosquito (*Aedes albopictus*) and *Ochlerotatus japonicus.* Both are Euro-Asian species that are found in natural and artificial containers that hold rain water. The Asian tiger mosquito has not yet become permanently established in Connecticut, but has become a major pest in New Jersey. The potential expansion of these introduced mammal-biting mosquitoes into Connecticut poses public health impacts since both species are known vectors for diseases including Eastern Equine Encephalitis and West Nile Virus. If temperatures continue to rise and rainfall patterns change in frequency and intensity, the result could be an increased mosquito season that would increase the exposure and risk to humans of mosquito and other vector-borne diseases.

What the Department is Doing

The CTDEP's goal is to maintain healthy, diverse, sustainable wildlife populations by conducting species management, research, inventories, and habitat management. Many of the programs currently in place to address the threats identified in the CWCS will increase the resilience of Connecticut's wildlife and habitats to climate change. It is important to realize that climate change will disrupt ecosystem function, increasing the probability that certain species, such as deer or an invasive species, could benefit disproportionately and tip the ecosystem further out of balance. Science-based active management will be required to moderate the impacts of climate change. Regulated hunting and trapping seasons are important management tools and will be administered to regulate wildlife populations at levels consistent with human and ecological tolerances.

A great deal is being learned about the distribution, life history and habitat requirements of some of Connecticut's rarest species through projects initiated under the federal/state State Wildlife Grants (SWG) program. The SWG program was developed with the goal of "keeping common species common" while also protecting those of greatest conservation need. The results of SWG projects have led to better understanding of the status of many species that were not well studied in the past. The information derived from these projects can serve as baselines for monitoring the impacts of climate change and for developing adaptation strategies.

The Natural Diversity Data Base (NDDB) maintains geospatial information on state-listed (rare) species and this information is provided to land use decision makers to guide responsible growth. As part of Governor Rell's Responsible Growth Initiative, the Wildlife Division, in conjunction with the University of Connecticut, is mapping key habitats for wildlife species with the greatest conservation need. This information will be incorporated into the NDDB. For many taxa, the NDDB is incomplete and the CTDEP is attempting to fill in the data gaps with new surveys. The data in the NDDB must be as comprehensive as possible in order to effectively guide wise development and monitor species trends due to climate change and other factors.

After managing wildlife for decades in a relatively stable environment, the state and federal agencies will have to adapt to and forecast in an environment that is increasingly affected by climate change. The CTDEP is working with other state agencies, federal agencies and conservation organizations to assess and adapt to the impacts of climate change on a regional level. Climate change is a real phenomenon that will impact the

distribution of plants and animals in the Northeast. This landscape level approach will allow Connecticut to identify vulnerable habitats and wildlife species and project where these habitats and species may be sustained into the future, regardless of political boundaries. Certain states will assume responsibility for vulnerable species if they possess current and future habitat for them. For example, the New England cottontail may be viewed as a "responsibility species" for Connecticut since our state appears to have the best remaining populations of this species.


Research on New England cottontails

Using the New England cottontail as an example, the CTDEP is documenting the distribution of the species and is conducting research to identify attributes that make certain habitats important to them. Several projects are underway to enhance existing New England cottontail habitat. The CTDEP is using a variety of cooperative agreements with conservation partners to protect core habitats that are large enough to ensure genetic viability and continued survival in the face of climate change and other threats.

Because the impacts of climate change on wildlife are based upon projections, the region will be using a technique called "adaptive management" in which actions are implemented, scientifically monitored, and then refined based upon the observed results. Adaptive management allows New England to move forward using the best science at hand and then learn by doing and develop new actions. State and federal agencies are gearing up to improve networking, data sharing and monitoring to improve communication and reduce duplication of efforts in response to the changing climate. The Northeast Association of Fish and Wildlife Agencies will be a key coordinator of these regional efforts. (Implications for fish species are reviewed in the Fisheries fact sheet).

Habitat Management - The CTDEP manages wildlife habitat on state land, primarily Wildlife Management Areas and State Forests, using a variety of tools. Because early-successional habitats and the wildlife that depend upon them are declining, many of the habitat management activities are directed towards reversing natural succession to create and maintain grasslands, shrublands and old fields. Timber harvesting, brush mowing, and burning are used to maintain early successional habitats on state land. (Additional forest management techniques are detailed in the Forestry fact sheet).

With over 90% of Connecticut under private ownership, the need for private lands habitat management for rare and declining species is overwhelming. Through the federally funded Landowner Incentive Program (LIP), the Wildlife Division provides technical assistance and cost assistance to landowners for habitat management that results in the protection, restoration, reclamation, enhancement and maintenance of habitats that support species at risk. In addition, the Natural Resource Conservation Service administers a Wildlife Habitat Incentive Program (WHIP) that encourages landowners to maintain or establish wildlife habitat. Privately held land will be a critical component in linking current habitats to future ones in response to climate change.

The CTDEP Wetland Restoration Program works statewide, but primarily in coastal areas to restore the natural hydrology in degraded marshes and to restore native vegetation by eliminating monocultures of the invasive plant, *Phragmites*. The Wildlife Division's Wetland Habitat and Mosquito Management Program staff works with the CTDEP Wetland Restoration Unit to design and implement Open Marsh Water Management and other wetland enhancement techniques to improve wildlife habitat and control mosquitoes. As a result of the CTDEP restoration efforts, Connecticut's coastal wetlands have been enhanced to the benefit of the plants and animals that require these habitats. However, the projected rise in sea level could impact these marshes and many sites are hemmed in by development preventing inland migration of the marsh. The CTDEP is identifying locations where such habitat migration opportunities do exist and attempting

to protect these areas through acquisition or other means.

The CTDEP has implemented a Grassland Habitat Initiative to secure and expand the amount of habitat in the state that will support grassland-obligate species. The initiative promotes a public/private partnership to create and maintain grasslands and this model could be used to protect other imperiled habitats as well.

Land Protection and Conservation - The CTDEP has acquired many ecologically important properties over the past decade. In anticipation of the shifts in ranges that will occur in future decades due to the changing climate, more attention needs to be directed towards connecting large blocks of habitat so that species have room to migrate inland, upward in elevation, and northward. The CTDEP will not be able to purchase enough lands to make all of these connections, but should evaluate other ways to piece together corridors, critical habitats and potential habitats. The CTDEP is in the process of mapping all protected open space in the state, regardless of ownership, and the results of this project will assist the CTDEP in targeting gaps where additional land protection should be prioritized.

In Conclusion - It is important to recognize that humans will not be able to sustain all species and all habitats in the face of climate change. Connecticut will lose species and will gain species over time. These changes will have to be evaluated and planned for at the landscape, rather than the state level. In other words, the question becomes, how will society sustain biodiversity in the Northeast, rather than in Connecticut alone.

While the ranges of plants and animals will shift, they will do so at different rates. Whole ecosystems will not shift at the same time. New assemblages of plants and animals will develop and will have to be monitored and studied over time.

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IMPROVEMENTS AND CHALLENGES FOR TODAY

Individual, Corporate, Municipal and State Stewardship

- Conduct vulnerability assessments for wildlife species at risk and their habitats.
- Determine "responsibility species" in concert with regional conservation partners.
- Identify species and habitats that Connecticut is likely to lose and evaluate the consequences on a landscape level.
- Identify core habitats for species at risk; enhance and enlarge them if possible.
- Build connectivity into habitat protection strategies; include all conservation partners to coordinate management of privately and publicly protected land.
- Continue and enhance the management of potentially overabundant species, such as deer, to prevent ecological damage.
- Maintain trapper and hunter numbers to conduct viable management programs.
- Promote responsible growth and discourage actions that increase habitat fragmentation.
- Educate the public about the threats to native wildlife and the critical importance of private lands stewardship. Promote incentives for private land habitat management.
- Improve communication, monitoring and data exchange between state and federal agencies and conservation partners working on climate change adaptation.
- Protect important wetlands, streams and vernal pools by establishing adequate buffers.
- Manage and enhance habitats on state land and monitor wildlife response.
- Conduct research to better understand wildlife/habitat relationships for species at risk.