# Freshwater Ecosystems

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Climate change will affect Maine's lakes, rivers, and wetlands by altering the timing and magnitude of precipitation, length of growing season, spring ice-out, and spring runoff.

As a result, warming water will reduce the distribution of cold-water fisheries, the ice fishing season will be shorter, and local flooding and stream erosion damage may become more common in some areas.

Freshwater supply, especially in coastal communities, will become less reliable due to altered hydrology, rising sea level, and increased demand.

Thanks to a history of glaciation and a humid climate, Maine has thousands of lakes and ponds, thousands of miles of streams and rivers, plentiful groundwater aquifers, and numerous wetlands such as bogs, swamps, and marshes. All this water supports a diversity of ecosystems, plants, and animals, and provides valuable services to humans, such as drinking water and crop irrigation.

D.J. Fernandez

## Climate and freshwater ecosystems

Temperature, precipitation, and timing of significant aquatic events (intense rain, ice-out, spring flooding, drought, etc.) are "master variables" that influence freshwater ecosystems and that are predicted to change according to all climate model predictions (*e.g.*, this report and Hayhoe *et al.* 2007). Local effects, such as stream flow, have been linked directly to global-scale climate behavior (Kingston *et al.* 2007).

Changes in temperature will affect the abundance and distribution of freshwater plants and animals. Increased air and water temperatures will increase overall production in lakes, ponds, rivers, and streams, as plant growth is enhanced in warmer surface waters. Warmer temperatures and more frequent rainstorms also might increase the incidence of West Nile virus and other mosquito-borne diseases (Poff *et al.* 2002).

This preliminary assessment predicts a wetter future, with more winter precipitation in the form of rain (*Figure 9*). Other assessments forecast increased intensity of precipitation (Hayhoe *et al.* 2007). Although it is not possible to predict specific changes at a given location, several 100- to 500-year precipitation events have occurred in recent years.

Changes in climate will affect the inputs of water to aquatic systems in Maine and changes in temperature will affect freezing dates and evaporation (Huntington *et al.* 2003). These changes will drive changes such as earlier spring runoff, decreased snow depth, greater lake level fluctuations, and saline intrusion of coastal aquifers. A number of stream gauges in Maine show a shift in peak flows earlier in spring and lower flows later in the season (*Figure 15a*; also Hodgkins and Dudley 2006). Similarly,

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## Changes in Timing of Maine River Flows, 1952-2007

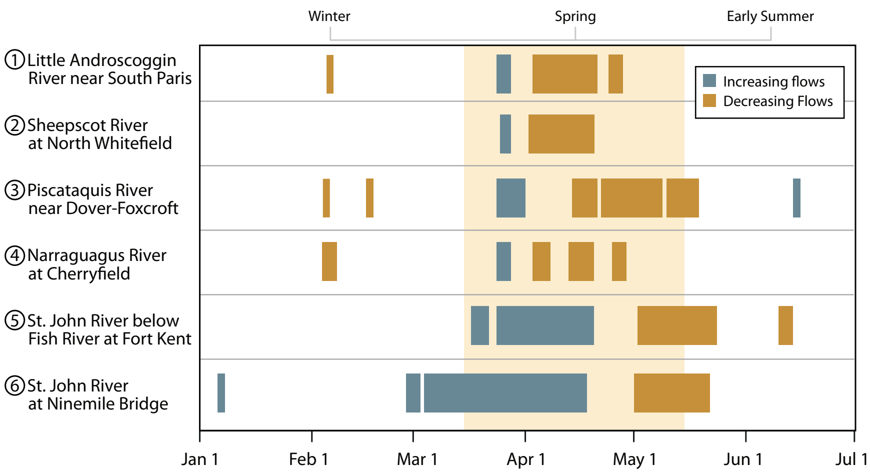


**Figure 15a** Stream gauges across the state (see maps) show statistically significant increases (blue) and decreases (brown) in river flows in late winter and spring, respectively. The shaded block represents the regulatory season used by the Maine Department of Environmental Protection to prescribe season-specific Aquatic Base Flow levels. A Mann-Kendall statistical test on daily streamflow data confirmed trends during the period (Ricupero and Jain 2008).


## Ice-out Records for Selected Maine Lakes

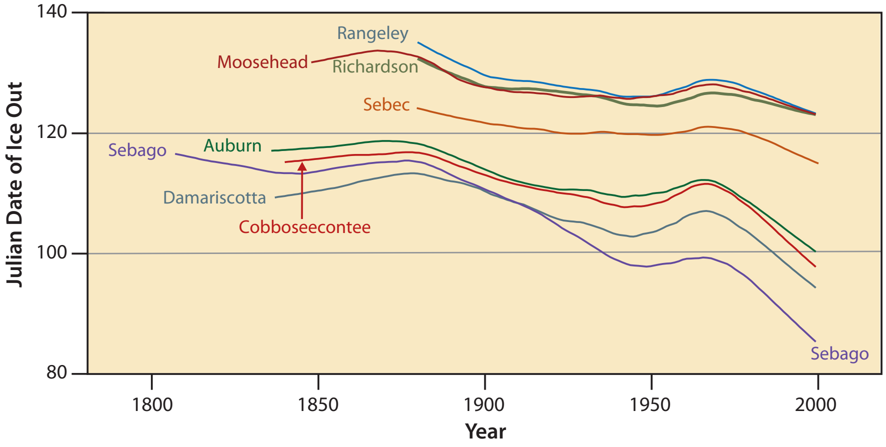


**Figure 15b** Lake ice-out dates, or the dates of ice break-up, are the annual dates in spring when winter ice cover leaves a lake. Lake ice-out dates in Maine have advanced by up to two weeks since the 1800s (Hodgkins *et al.* 2002).

lake ice-out dates in the New England region have advanced by up to two weeks since the 1800s (*Figure 15b*; Hodgkins *et al.* 2002, Hodgkins *et al.* 2003), resulting in shorter seasons for ice-fishing, skating, skiing, and snowmobiling. Southern Maine could ultimately stop having safe ice conditions.

The timing of spring snowmelt influencing river flows and the warming of waters are critical events in the lives of water-dependent wildlife. Warming water and spring rains trigger spawning for salamanders and frogs, while spring flows and water temperatures signal hatching times for aquatic insects like mayflies, stoneflies, and dragonflies. Water levels and temperatures also cue migration of sea-run fish such as alewives, shad, and Atlantic salmon into our rivers, and the arrival or concentration of birds that feed on these fish.

Lower flows in summer will reduce aquatic habitats like vernal pools, cold-water holding pools, and spawning beds. If we experience longer periods without rain, Maine's thousands of acres of peatlands, marshes, and forested swamps could dry out, releasing stored carbon and other greenhouse gases. Increases in severe storms (and droughts in between) will change the boundaries of wetlands as they adjust to fluctuating water levels. For example, the unique floodplain forests of the Saco, Penobscot, upper Kennebec, and Sebasticook rivers could convert to meadow or upland forests.

Changes in the water cycle will interact with changes on land. Water flowing through watersheds where tree and plant communities are changing in response to climate will deliver altered inputs of nutrients and organic matter into lakes and streams, changing their chemistry and biota. For example, the trend of decreased calcium in lakes is leading to the demise of zooplankton species that are important to lake food webs (Jeziorski *et al.* 2008).

Surface water recharges groundwater, and groundwater provides baseflow to streams and rivers during periods of low rainfall. As the surface water regime changes, so too will the timing and delivery of recharge to groundwater.

More frequent large storms and scouring flows will damage habitat, especially where aquatic systems are already stressed by increased runoff, poor water quality, and siltation of lakes and stream beds. These disruptions ripple through watersheds, altering stream flows and re-distributing sediments, affecting infrastructure such as the size and ratings of culverts and bridges. As a result, roadway flooding, dam breaches, or wash-outs may occur more frequently.

### The future of Maine's freshwater resources

Some of the ecosystem processes affected by changes in temperature and hydrology have direct societal costs. Maine lakes attract residents and visitors for fishing, paddling, and wildlife watching, generating $3.5 billion each year (Maine Congress of Lake Associations 2006). Many of Maine's lakes supply high-quality drinking water. Warmer water and increased nutrients from stormwater runoff threaten to degrade lake water quality through more frequent or more intense algal blooms, with resulting effects on waterfront property values. Severe storms can flood waterfront properties, causing expensive damage.

Demands on freshwater supplies in the US are increasing, and water shortages are likely in the near future (GAO 2003). In the New England region, freshwater withdrawals are projected to increase by 550 million gallons per day, or 15%, over the next 20 years (Brown 1999). In coastal areas, increasing residential development and tourism will raise the demand for water at the same time as warmer temperatures and salt water intrusion threaten water quality.

### Opportunities & Adaptation

While freshwater availability is a critically important factor influencing socioeconomic development, the maintenance of water quality and ecosystem services can have far-reaching effects on the long-term sustainability of river systems. In a changing climate, added stresses from urbanization and land-use change present an important challenge in balancing human and ecosystems water needs. Maine has recently promulgated a first-in-the-nation water regulation that limits water withdrawal from rivers and lakes with a goal of maintaining the integrity of the river and riparian ecosystems. These laws regulate human consumptive uses to protect aquatic systems, based on *current* hydrological conditions. Compliance with these regulations may be impossible when hydrologic conditions change in response to climate shifts, unless flexibility and adaptive management are incorporated during rulemaking.

It is not unreasonable to imagine a time in the future when water-starved regions begin eyeing Maine's abundant freshwater supplies, and the potential for conflict inherent in such a scenario. We have already seen suggestions of this conflict, in Downeast Maine where blueberry farmers drew irrigation water from rivers home to endangered Atlantic salmon; in western and southern Maine where commercial bottlers continue to search for and develop new water sources; and in coastal Maine where the 2001-2002 drought magnified imbalances of drinking water supply and demand (Schmitt *et al.* 2008). Although public debate has begun on how water from Maine could/should be sold for profit by private companies, water resource managers and other communities should anticipate that the value of "their" water could become more contentious. As peaks in demand increase, water managers will have to look further afield for new supplies, or pursue costly interconnections with neighboring supplies, at the same time that suitable water sources become scarcer.

Finally, we need to know the extent to which key species (*e.g.*, brook trout) can respond to increasing water temperatures by moving to cooler (*e.g.*, more northerly) habitats, and how such movements are constrained by barriers to mobility, such as culverts. Depending on the answers to these research questions, we might accelerate barrier removal efforts to increase the resilience of key species. Policy will need to address what measures will be taken to protect ecologically unique species in the event that they are unable to adapt. For example, constructing and managing artificial wetlands may be needed to preserve these ecosystems from seasonal drought.

### Knowledge gaps

Where are freshwater ecosystems (lakes, floodplains, wetlands) most vulnerable to floods and droughts, and are management techniques (*e.g.*, maintaining water levels) available to help maintain resilience in the face of these extremes?

Increased warming is likely to increase the susceptibility of Maine's aquatic flora and fauna to new pests and pathogens. How will this affect large areas of habitat conversion and species loss or displacement?

Roads with improperly sized and placed culverts and bridges fragment river and stream habitat, preventing the movement of aquatic species. Roads and related development also alter the surface and subsurface flow of water through the landscape to aquifers, streams, and ponds. How will less predictable weather and seasonal changes enhance or interact with these stresses?

Much of our infrastructure for water delivery, wastewater transport, and transportation is not designed to handle the predicted increase in intense precipitation events. What happens when flood zones, bridges, culverts, and water treatment plants designed for "20-year" storms are overwhelmed with sediment and other precipitation-related pollutants? How will Maine's current hydroelectric power regime be influenced by expected changes in seasonal hydrology, storm events, and river levels?