


FOCUS

Climate change and River Flows

study conducted by

J. David Allan and Vilan Hung
University of Michigan, Ann Arbor, Michigan

The 200,000 miles (~325,000 km) of rivers and streams in the Upper Great Lakes (Minnesota, Wisconsin, and Michigan) region contribute significantly to the region's multi-million dollar tourism industry. The Au Sable River is world renown as a recreational fishing "spot" in Northern Lower Michigan. Still, these waters provide more than just places to relax and fish. They provide important goods and services to the 18 million people of the three-state region. They provide water for drinking and for hydropower generation. They provide highly desirable riverfront property. They provide an important ecological role – many species occur primarily or exclusively in these river corridors that act as critical links between forest fragments. For example, the world's last known population of the white catspaw pearly mussel (Epioblasma obliquata perobliqua) is found in Fish Creek, which is a small tributary of the Maumee River in Indiana and Ohio. The copper redhorse (Moxostoma hubbsii) is a fish whose world distribution is limited to the lower Richelieu River (which drains Lake Champlain) and the adjacent St. Lawrence River.

Current Stresses

Over the years, Great Lakes rivers have been subjected to numerous stresses. For example, the logging era resulted in cleared land, which led to warmer streams and increased sedimentation, which was further exacerbated by floating the logs to river mouths. Today, Grayling, Michigan, is a popular recreational destination, but its namesake, a salmonid fish much sought after by fly-fishers in Alaska and Canada, was extirpated early in the 1900s. Other types of habitat destruction, invasions of non-native species, and chemical pollution are amongst the most important current stresses. Agriculture and sprawl are common examples of how changing land use and population can influence the delivery of sediments, nutrients, and contaminants into surface waters. Climate change will add yet another stress.

Impacts of Climate Change

Assessing the impact of climate change on streamflow is complicated because of the anticipated competing effects of climate change. The wetter conditions that are expected by the end of this century could increase streamflow. But the warmer conditions that are expected could increase evaporation and decrease streamflow. Additionally, vegetation may increase, further increasing transpiration from plants – particularly in the summer. The diverse hydrogeography of the region also has to be considered. Figure F5.1 shows that rivers at the northward limit of the region are primarily snowmelt-driven

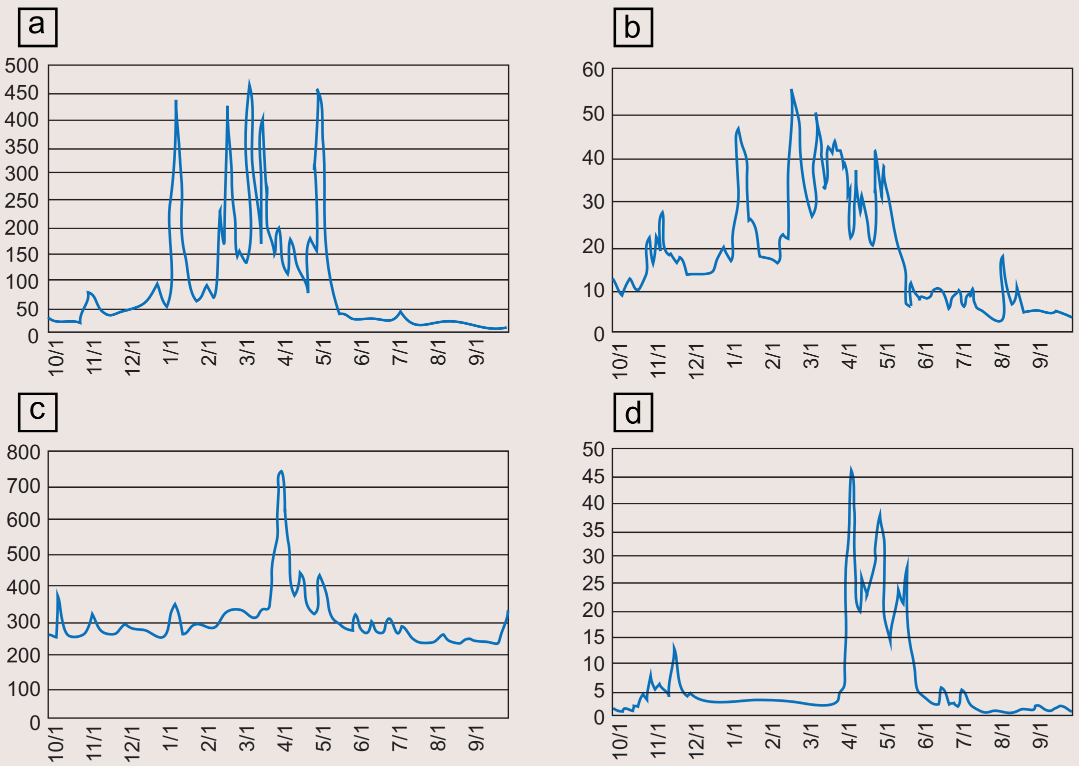

Figure F5.1: Annual hydrographs of four river types characteristic of the Great Lakes region. a) Snowmelt and rain driven stream flow; b) Perennial event-responsive streamflow; c) Perennial, super-stable streamflow; d) Snowmelt-driven streamflow.

(e.g., Sturgeon River), while farther south, rivers exhibit a combination of snow-melt and rain-driven streamflow (e.g., Red Cedar River). Other heartland streams exhibit perennial runoff (e.g., Huron River).

Stream-Flow Patterns and Temperatures

Despite these competing effects and complexities, it is likely that seasonal streamflow patterns will be strongly affected. Peak flows in the upper Midwest will likely occur earlier in the year, because of warmer winters and increased winter runoff. Summer baseflows may be lower, because of increased evapotranspiration, especially during dry years. A large number of rivers in west-central Canada have exhibited earlier spring runoff, particularly in recent years [F5-1]. Seasonal changes in streamflow may be considerable, particularly in the most northerly locations. An expected increase in the frequency and intensity of heavy precipitation and drought events will translate to greater variability in streamflow, which in turn will influence river ecosystems [F5-2].

Stream water temperatures will also likely increase because they are primarily determined by air temperatures. But, they will exhibit considerable local variation due to shading, the interconnection of rivers with lakes and wetlands, and the extent of groundwater supply [F5-3]. Warming effects will be greatest for rivers which have little riparian shading and which receive lesser inputs of groundwater. A study of summer maxima in small tributaries of the River Raisin, southeastern Michigan, reported a surprisingly large range of temperatures, from 73-102°F (23-39°C) [F5-4]. Statistical analysis indicated that if riparian shade was restored, then summer maxima would not exceed 84°F (29°C).

Biological Diversity

The elevated stream temperatures will have complex effects on the biota of rivers. Biological production in aquatic ecosystems increases logarithmically with temperature, and so higher overall productivity might be anticipated. Rates generally increase by a factor of 2-4 with each 18°F (10°C) increase in water temperature, up to about 86°F (30°C) [F5-5]. Other studies reported macroinvertebrate production to increase 3 to 30% for each 1.8°F (1°C) increase in temperature, based on a survey of 1,000 stream studies at mid to high latitudes [F5-6]. However, complexities associated with food webs, along with changing species composition, possibly including non-native invasions, render speculative any predictions of higher productivity. Range shifts will also likely occur. Species extinctions and extirpations will occur at the southern limit of species ranges. Ranges are expected to extend northward if dispersal corridors and suitable habitat are available. Some studies suggest that a 7.2°F (4°C) warming would shift the center of distribution for aquatic invertebrates northward by about 400 miles (640 km). [5-7]. An increase of 7.2°F (4°C) in air temperature should move the simulated ranges of smallmouth bass and yellow perch northward in Canada by about 312 miles (500 km). A national analysis of the change in habitat availability for cold-, cool, and warm-water fishes predicted significant loss of suitable thermal habitat for all three groups [F5-8]. Only a few species of warm-water fishes benefited in these simulations. Fish diversity in the streams and rivers to the south of Michigan, Wisconsin, and Minnesota is considerably higher than in the heartland region [F5-9]. Using the widely quoted figure of a northward shift of 312 miles (500 km) in species distributions with a 5.4°F (3°C) warming, biological diversity of heartland rivers is expected to increase, as more diverse fauna south of the heartland disperses northwards.

While higher ecosystem productivity and greater biological diversity are long term expectations, the shorter-term (decadal to 100+ year timeframe) expectation is uncertain. Dispersal opportunities, habitat suitability for poleward-dispersing species, and changing biotic interactions as consequences of changing species assemblages raise the possibility that both productivity and diversity may be adversely affected. Biotic interactions are likely to be altered by shifts in community species composition, with difficult to predict consequences. At least initially, climate change may benefit a small number of species because of temperature tolerance, dispersal capabilities, or general adaptability. Acting as competitors or predators, those species that initially benefit from climate change may severely impact other species already stressed by changes in temperature and streamflow.

The availability of suitable north-south dispersal routes complicates the response of the biota to climate change [F5-10]. The rivers of the heartland region fall within three great river basins of North America: the Mississippi, the Nelson, and the St. Lawrence including the Laurentian Great Lakes. Invasion by the rich fish fauna of the Ohio region into the Laurentian Basin is impeded by land barriers. Likewise, faunal dispersal from the Mississippi to the Nelson drainages is unlikely to occur naturally. However, the north-south orientation of the Mississippi and St. Croix drainages suggests that dispersal in response to climate warming should occur relatively easily. Humans accidentally and purposefully introduce species into new habitats, and this may result in a leap-frogging of natural barriers. The Calumet River, whose flow was reversed for sewage disposal, now forms a water connection (the Chicago Sanitary and Ship Canal) between the Mississippi and Laurentian Basins, and evidently allowed zebra mussels to invade the Mississippi system. Man-made canals, bait-bucket transfers, and stocking by private individuals and public agencies all may enhance trans-basin dispersal.

Coping Strategies

Hydrologic regime is altered by changes in land use as well as by dams, diversions and other direct modifiers of flow. Societal decisions regarding instream structures and land use can increase or minimize the impacts of climate change. Coping and adaptation strategies include changes in dam management (including flow management and dam removal) and in land management (including conversion of land use and management of streamside or riparian zones). Those rivers linked to lakes, reservoirs and wetlands, fed by quickflow, and with minimal riparian vegetation will experience greater change in water temperatures than will shaded, groundwater-fed rivers with few connections to standing water. Management of riparian vegetation and of human activities that affect quickflow (e.g., farm and city drainage systems, impervious surfaces) are important coping and adaptation strategies.

Over the long term, the biota is expected to change to reflect altered flow and temperature characteristics under future climates. Productivity and diversity both may increase, and anglers will find different sports fishes in their favorite locations. In the short-term, however, rates of dispersal and colonization may lag considerably behind rates of climate change. Local fisheries may experience decades of decline before re-equilibrating. Given the high value of sports-fishing in the Heartland region, local economic effects are likely to be considerable. Ecological science does not presently have the capacity to manage entire ecosystems. Following guidelines of adaptive management, fisheries managers will need to experiment with management practices to cope with changing ecological conditions.