The Great Lakes basin holds the world's largest supply of surface freshwater and is home to over 35 million people. Climate change is predicted to have major impacts on the natural resources of this system, which will exacerbate existing problems and create new challenges. This series of policy briefs explores several impacts of climate change and emphasizes the need for responsible stewardship of our vital water resources.

Climate Change Impacts on Habitat and Wildlife Protection and Restoration in the Great Lakes Basin

A healthy ecosystem benefits the extensive coastlines, numerous wetlands, connecting greenways, and regional watersheds of the Great Lakes basin by providing habitat essential to support and sustain native wildlife. Healthy habitats protect drinking water sources, control floodwaters, minimize erosion and sedimentation, and provide shelter for native and migrating species.

Great Lakes terrestrial and aquatic habitats face many threats. Development, altered flow regimes caused by dams and other control structures, and the introduction of toxic substances and excess nutrients all contribute to the degradation of functional ecosystems. These threats also alter food webs and impact biodiversity. Protection and restoration of terrestrial and aquatic ecosystems will create highly functional habitats for wildlife and may assist in adapting to the impacts of climate change.

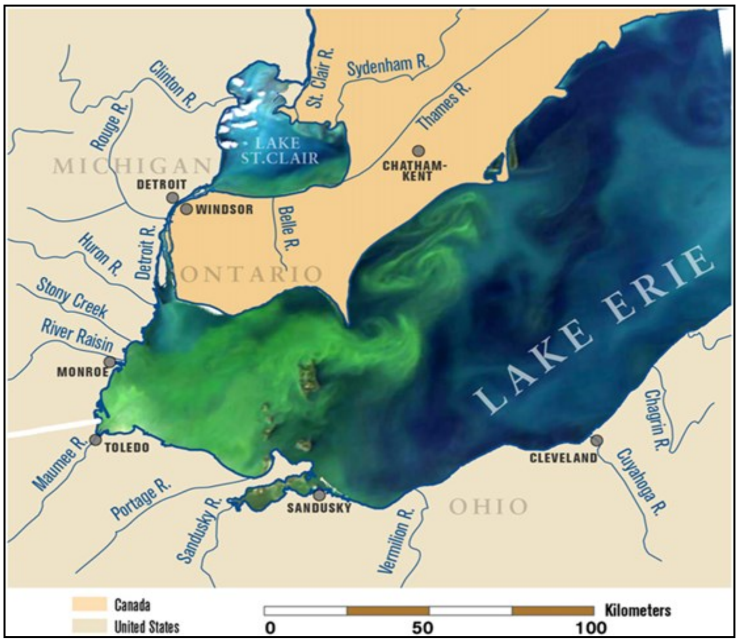

Figure 1. Algal bloom in western Lake Erie. Source: Michalak *et al.* 2013.

Impacts of Climate Change

Great Lakes habitats face climate change impacts such as increased water temperatures, decreased annual ice cover, decreased lake levels, altered precipitation patterns, and increased air temperature (Magnuson *et al.* 1997, Lofgren *et al.* 2002). Anticipating potential impacts will be difficult and highly dependent on locale. For example, while warmer water temperatures in southern Lake Michigan may minimally influence certain fish species, similar increases in northern Lake Superior would negatively impact the quality of cold-water fisheries for spawning and the thermal limits for growth of certain fish species (Ng & Gray 2011). Protection and restoration of Great Lakes habitats provide the region with the most effective method to address several impacts of climate change outlined below.

Altered Coastal Shorelines and Wetlands

A pattern of decreased annual ice cover in the Great Lakes region is observed in long-term climate trends. Warmer water temperatures and decreased winter ice cover may lead to lower lake levels due to greater annual evaporation. Lower lake levels may alter coastal shorelines, thereby exposing new habitat for terrestrial species. At the same time, wetland areas could be diminished, effectively decreasing and isolating acceptable habitat available to aquatic species (Hellmann *et al*. 2010, Gronewold *et al.* 2013).

Sustained Stratification

Lake stratification occurs when temperature differences exist between water at different depths, and warmer surface water may intensify this stratification (Paerl & Paul 2012). Seasonal mixing of layers provides oxygen and nutrients to fish habitat. Less ice coverage could negatively impact the quantity and quality of nutrients available to fish in their preferred water temperature by altering stratification trends. Combined with warmer lake temperatures, altered stratification trends also promote growth of harmful cyanobacteria over beneficial primary producers, impacting food webs (Paerl & Paul 2012).

Warmer Fisheries Habitat

Changes in lake temperatures may impact fish habitat. Less winter ice cover could negatively impact reproduction of certain species, such as whitefish, that require ice cover to protect spawning beds from winter storms (Kozacek 2014). Cold-water species may experience heat stress when water temperatures exceed their upper optimum temperature, leading to decreased growth (Ng & Gray 2011). Growth and abundance of predator fish, such as lake trout, may also be impacted by predator-prey interactions related to thermal dynamics. The abundance of predators, or lack of prey, is heavily contingent on water temperature in preferred habitat and could influence bioaccumulation of toxins in predator fish (Ng & Gray 2011). In predicted warmer lake water, new species may also be introduced, thus creating competition for food and altering the food web (Ng & Gray 2011).

Increased Runoff and Toxins and Nutrient Loading

Toxins and nutrients washed into streams in runoff following intense storms may negatively impact water quality and dissolved oxygen levels. Increased levels of toxins and nutrients in streams and the Great Lakes may bioaccumulate in fish and affect primary productivity in coastal habitats (Michalak *et al*. 2013). Greater movement of nutrients into warmer waters could also promote algal blooms in the Great Lakes, as noted in western Lake Erie during 2011 (Michalak *et al*. 2013, Figure 1).

Greater stream runoff due to more frequent and intense precipitation events could also create new coastal wetlands beneficial for aquatic species and terrestrial species requiring wetland habitat for part of their life cycle. However, the diversity and density of fisheries and aquatic invertebrate habitats may be negatively impacted by changes in timing and volume of seasonal streamflows. Drought impacted areas may negatively impact fish habitat in low flow streams (Cherkauer & Sinha 2010).

Shifting Species Compositions

Shifts in phenology and ecological timing sensors, such as blooming and seed dispersal, due to higher annual temperatures and earlier spring warming may affect many ecological functions, agricultural ecosystems, and migration patterns. Warming regional temperatures will shift USDA Plant Hardiness Zones upwards from 5b towards 6a in the southern Lake Michigan region (Hellmann *et al.* 2010). Such shifts will alter the species composition of trees and shrubs grown in the Great Lakes region (Figure 2). Changing climate will also impact distribution of habitat for native birds and terrestrial species, migrating species, as well as pests and invasive species.

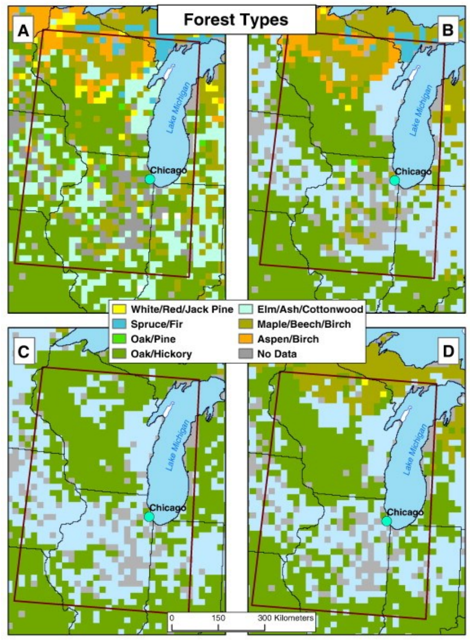

Figure 2. Forest-type maps as currently measured (A) and modeled under current (B), higher (C), and lower (D) emission scenarios for 2100. Source: Hellmann *et al.* 2010.

Conclusion

Warmer water temperatures, decreased winter ice cover, altered precipitation patterns, and increased air temperatures will impact Great Lakes coastal and aquatic habitats. Coastal and fisheries habitats and stratification trends will be altered by ice coverage patterns and warmer water temperatures. More frequent and intense precipitation events will deliver greater quantities of toxins and nutrients to Great Lakes habitats. Species compositions in terrestrial ecosystems will be shifted with warmer air temperatures. The uncertainty associated with climate change effects and their subsequent effects on habitat remains a challenge for scientists, managers, and policymakers. Nevertheless, projects benefitting wildlife habitat in the basin must incorporate factors of climate change to successfully protect and restore the Great Lakes ecosystem.

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