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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 Invasive Species in the Great Lakes Basin

More than 180 invasive species are outcompeting native species in many areas of the Great Lakes basin. These invasives are introduced through commercial shipping, canals and waterways, recreational activities, and trading of live organisms (Figure 1). Invasive species damage ecosystem health and have negative impacts on economic growth. They are extremely difficult and costly to eliminate once they have gained a foothold, making prevention the most cost-effective strategy to control their presence. Reducing and managing invasive species is vital to the health of the Great Lakes ecosystem.

Impacts of Climate Change

Climate change may increase the threat posed by invasive species in the Great Lakes. Higher air temperatures, which are likely to increase by as much as 7° C by 2090, will dramatically alter the existing ecosystem through the predicted increased water temperatures, higher evaporation rates, and reduced ice cover (Gregg *et al.* 2012). These climate change effects will impact invasive species in a variety of ways.

Altered Fisheries

As the Great Lakes region is predicted to warm, the range of many plant and animal species will shift north with the predicted change in climate zones. Species that remain will face competition from migrating invasive species. With the expected warmer water temperatures in the Great Lakes, 19 warm water fish species from the Mississippi River and Atlantic Coastal Basins have the potential to invade the lower Great Lakes. Of the fish species currently present in the lower Great Lakes (Lakes Ontario, Erie, and Michigan), eight could invade the upper Great Lakes (Lakes Huron and Superior). These 27 fish species are predicted to bring with them 83 species of parasites to their new habitats (Rahel 2008). Overall, the migration of native fish due to climate change is predicted to reduce revenue from Great Lakes recreational fishing, which generates $9.3 billion each year (Ficke *et al.* 2007).

Extended Growing Season

Increased water and air temperatures may increase the growing season for many Great Lakes species. For many invasive species, including zebra and quagga mussels, this will provide time to maximize the use of their main competitive advantage, high reproductive rates (Rahel 2008). In combination with shorter, milder dormant seasons, populations of prolific invasives will have few limitations on increasing their dominance over native species. The suitable habitat under three different predicted water temperature increases from coldwater, coolwater, and warmwater fish increased throughout the year (Magnuson *et al.* 1990).

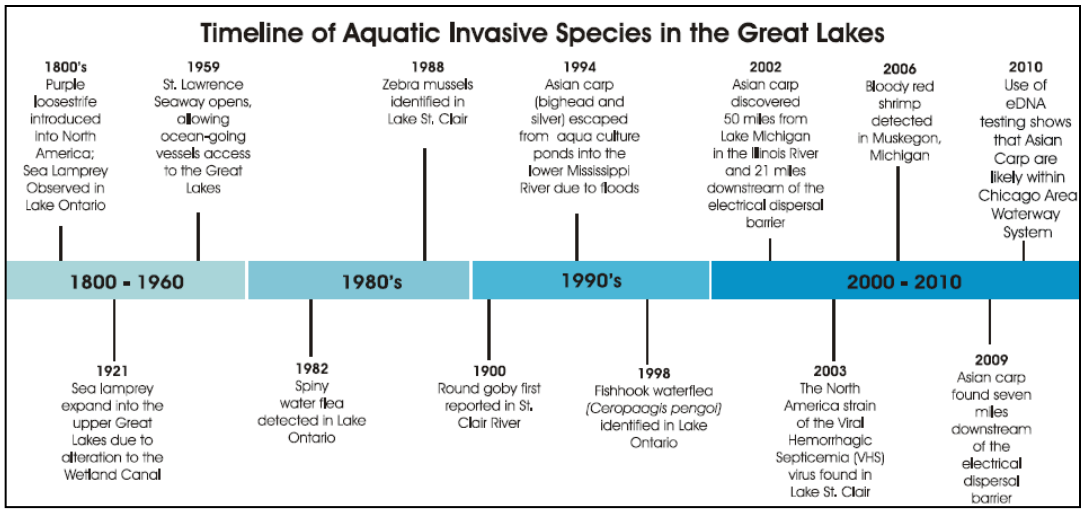

Figure 1. Timeline of most disruptive Great Lakes invasive species. Source: GLITF 2010.

Reduced Ice Cover

Predicted reduced ice cover due to greater air and water temperatures may have several implications for invasive species. Less ice cover allows solar radiation to keep surface waters warmer during winter, strengthening the density gradient and reducing mixing events between the hypolimnion and epilimnion. This could reduce the optimal habitat for many native species and provide favorable conditions

for invasives to establish themselves unchallenged (Figure 2). Reduced mixing will also alter the dissolved oxygen available to fish in deep water, creating an environment optimal for bottom-dwelling invasive species with low oxygen requirements, such as Asian carp (Ficke *et al.* 2007).

The potential reduced ice cover could also increase fish egg mortality during winter storms, presenting another challenge to native species (Gregg *et al.* 2012). Though the majority of native fish will likely be negatively impacted, opportunistic invasives may benefit from the changing habitat. Species currently living in a habitat cooler than their optimal environment will have a competitive advantage in warming water temperatures.

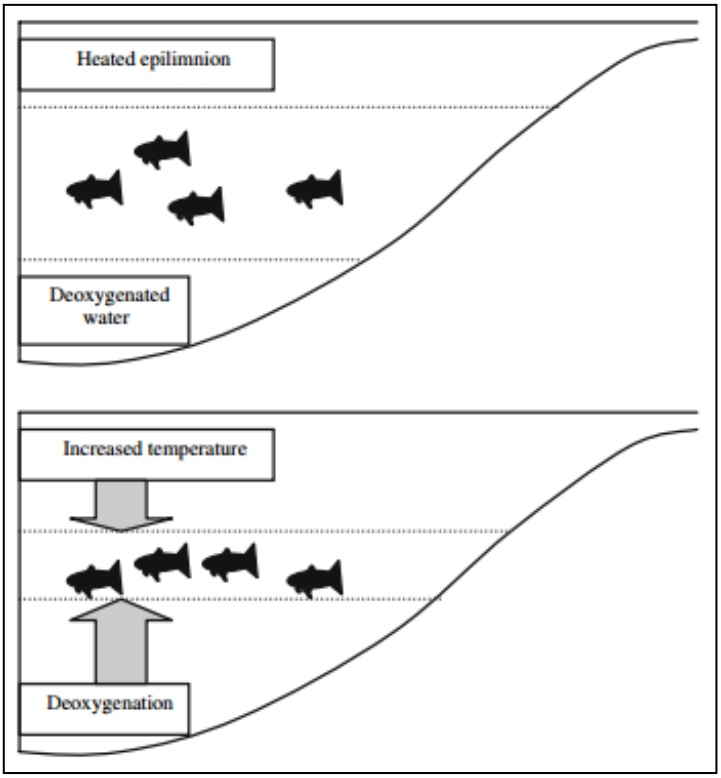

Figure 2. Climate change impacts on freshwater pelagic fish. Source: Ficke *et al.* 2007.

Altered Water Chemistry

Though the majority of climate change predictions result in improved circumstances for invasive species, some changes to water chemistry may have negative impacts. For example, expected higher levels of atmospheric carbon dioxide (CO_2) may decrease the competitive advantage of invasive mussels (Gregg *et al.* 2012). Higher atmospheric CO_2 levels increase the amount of CO_2 dissolved in the water, leading to a lower pH. Subsequently, saturation states of calcium carbonate decrease, and invasive mussels must expend more energy to synthesize and maintain their shells. Such expenditures take energy away from processes that give them a competitive edge, such as rapid filter feeding and reproduction.

Conclusion

Climate change will impact the Great Lakes basin in a variety of ways. Many of these foreseen impacts, such as shifts in climate zones, longer growing seasons, and reduced optimal habitat conditions for native species, will allow some invasives to extend their range in the basin. Alternatively, some impacts, such as decreases in pH, may hinder the spread and establishment of invasives. Whichever the case, climate change will affect the management of invasive species in the Great Lakes basin and must be meaningfully addressed in future policy and restoration efforts.

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