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Research article

Reeling in the damages: Harmful algal blooms' impact on Lake Erie's recreational fishing industry

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A B S T R A C T

Lake Erie is one of the most valuable natural resources in the United States, providing billions of dollars in benefits each year to recreationalists, homeowners and local governments. The ecosystem services provided by Lake Erie, however, are under threat due to harmful algal blooms. This paper provides recreational damage estimates using spatially and temporally varying algae measures and monthly fishing permit sales collected between 2011 and 2014. Results indicate that fishing license sales drop between 10% and 13% when algal conditions surpass the World Health's Organization's moderate health risk advisory threshold of 20,000 cyanobacteria cells/mL. For Lake Erie adjacent counties experiencing a large, summer-long algal bloom, this would result in approximately 3600 fewer fishing licenses issued and approximately \$2.25 million to \$5.58 million in lost fishing expenditures. Our results show a discrete jump in reduced angling activity upon crossing this threshold, with limited additional impacts associated with more severe algal blooms. This suggests that policies aimed at eliminating, rather than mitigating, algal levels are most beneficial to the Ohio angling industry.

1. Introduction

Lake Erie, shown in Fig. 1, provides \$10.7 billion in tourism benefits per year with a \$2 billion sports fishery (Great Lakes Commission, 2014). However, this large flow of benefits is under threat from a variety of sources including: Zebra Mussels, Asian Carp invasion, and more recently, increasing annual blooms of harmful cyanobacteria. Harmful algal blooms (HABs) impair water quality and often lead to public health warnings to either avoid drinking, swimming and in severe cases any contact with the water (Carmichael, 2001). In addition, it is predicted that the incidence of these blooms is likely to increase in duration and extent as a result of climate change and increased nutrient runoff which provide the needed resources for the bacteria causing blooms (Robson and Hamilton, 2003; Mooij et al., 2005).

Cyanobacteria, often referred to as blue-green algae, are one of the most common algae inhabiting Lake Erie and freshwater lakes across the Midwest (EPA, 2009). Cyanobacteria grow rapidly in the summer and fall months, when temperatures are elevated and the water column is stratified, and produce harmful algal blooms (HABs) that can last three to four month in duration (Michigan Sea Grant, 2017). These HABs often cover large areas of lakes and are capable of producing a number of toxins harmful to humans including *microsystin* (Carmichael, 1992). One of the more damaging HABs occurred in 2014 when 500,000 residents in Toledo, OH were warned not to drink their tap water due to increased *microsystin* toxin concentrations, subsequently leading to at least 60 hospitalizations (WTOL, 2014).

In addition to drinking water concerns, state and local authorities are increasingly forced to issue recreational public health advisories, warning recreators to avoid all contact with the water and providing a serious impediment to the success of local angling economies (Sohngen et al., 2015b; ODH, 2016). In other cases, algal blooms prevent sunlight from reaching the bottom of the water column and over time can lead to aquatic life dependent on this sunlight to diminish, significantly impacting the ecosystem and

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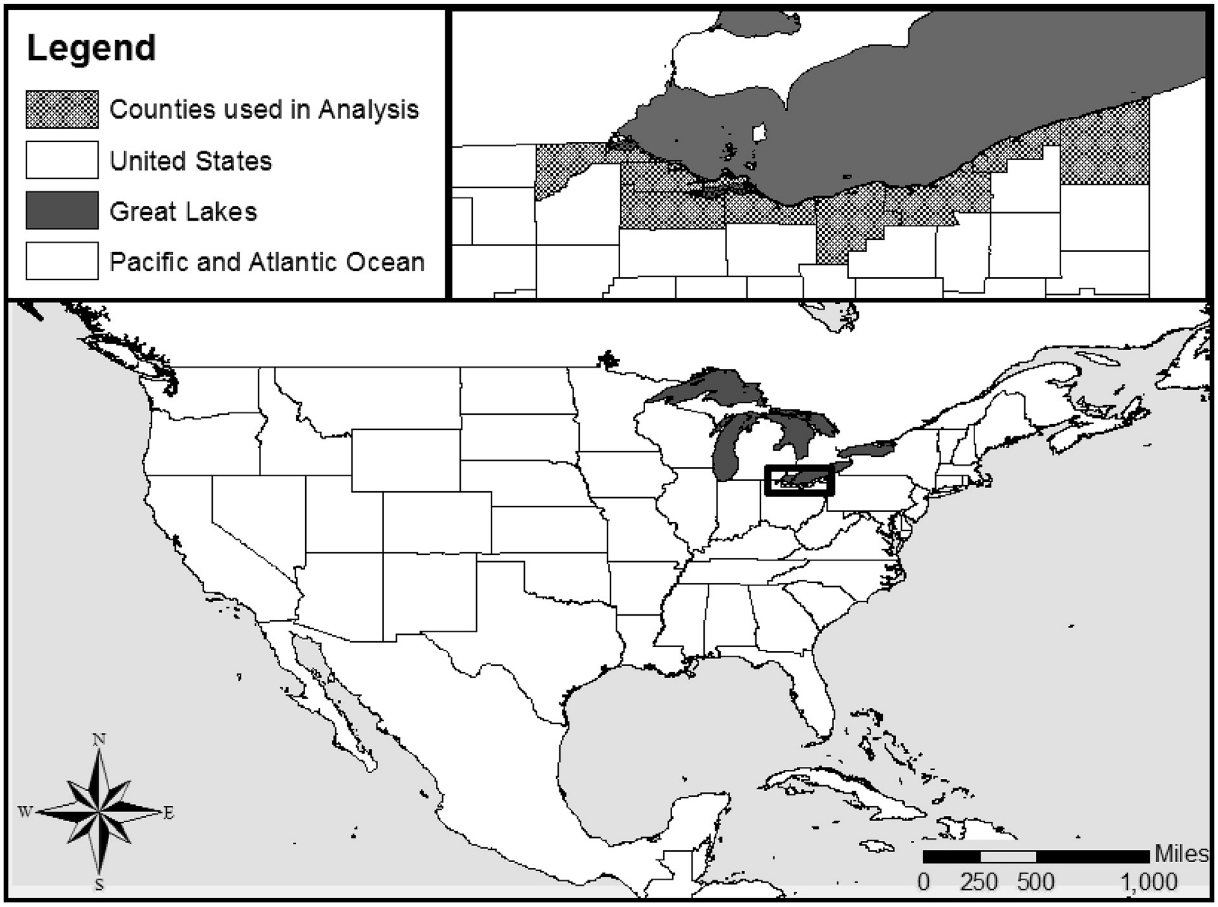

Fig. 1. Lake Erie and the United States.

harming the native gamefish populations (Potter et al., 1983; Landsberg, 2002). Whether through an explicit warning to stay away from the water or through the perceived impact on the likely catch-rate, the presence of cyanobacteria is likely to have a significant negative impact on recreation activities and the angling industry (Ludsin and Höök, 2013).

A number of policy recommendations aimed at managing or decreasing the presence of HABs have been suggested to address these potential concerns. Some of the more tractable, but potentially costly, management options include: implementing a tax on fertilizer application (Sohngen et al., 2015a), increasing the percentage of cropland reserved for buffer strips and wetlands (Scavia et al., 2016) and diversifying crop rotations within the Lake Erie Basin (Smith et al., 2015). Under each of these policy scenarios the policy-maker must consider the implicit tradeoffs made between the affected party (farmers) and the recipients (recreators/near lake homeowners/etc.). This tradeoff will determine the optimal management strategy and requires estimates of potential damages from algae blooms and costs of implementing these policies.

Linking water quality changes to residential and recreational decisions is an ongoing focus of applied researchers (Smyth et al., 2009; Kosenius, 2010; Vesterinen et al., 2010). A number of ecological and behavioral factors are known to influence water quality conditions; however eutrophication is often given special consideration due to its strong ties with human behavior. Increased application of synthetic fertilizers, urban waste water runoff and fossil fuel emissions have all been connected to more eutrophic conditions within freshwater ecosystems (Howarth et al., 2005). The diversity of potential causes of eutrophication has made it difficult for researchers to adopt a standardized measure of eutrophication in applied research. Consequently a number of empirical measures have been used as a proxy including suspended solids and dissolved nitrogen (Poor et al., 2007), lake depth (Bejranonda et al., 1999), fecal coliform (Leggett and Bockstael, 2000), and pH levels (Tuttle and Heintzelman, 2015). Across these studies, causal relationships emerge linking water quality changes to economic variables of interest.

In much of this literature a positive relationship between water quality improvements and nearby property values has been established (see, e.g. Gibbs et al. 2002; Boyle et al., 1999; Poor et al., 2007; Walsh et al., 2011) using a wide range of data, research designs and empirical strategies. Further causal relationships have emerged from the stated preference and choice experiment literature using boating, fishing, swimming and other recreational data. Anglers in New Zealand, for example, were estimated to have aggregate damages of at least $7.9 million USD caused by the spread of the invasive, nontoxic algae, Didymosphenia Geminate (Beville et al., 2012).[1] Additional studies focusing on the Black and Baltic Seas found a willingness to pay in Bulgaria of 0.27% of annual income to eliminate algal blooms in a nearby bay (Taylor and Longo, 2010). A contingent valuation study of the Baltic Sea drainage basin estimated that a reduction in eutrophication through a 50% reduction in nutrient loading would be valued at $3.4 billion USD per year across the basin, although this value takes into account

[1] This is equivalent to the $10.5 Million NZ found in the original study converted to USD at an exchange rate of 1 USD to 0.7543 NZ.