ARTICLE IN PRESS

Ecological Engineering xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Solving Lake Erie's harmful algal blooms by restoring the Great Black Swamp in Ohio

William J. Mitsch[a,b,*]

[a] Everglades Wetland Research Park, Florida Gulf Coast University, 4940 Bayshore Drive, Naples, FL 34112, USA
[b] The Ohio State University, Columbus, OH 43210, USA

ARTICLE INFO

Keywords:
Phosphorus
Agricultural runoff
Nonpoint source pollution
Wetland creation and restoration
Laurentian Great Lakes
Harmful algal blooms
Anthropocene

ABSTRACT

Harmful algal blooms are now a common occurrence around the world in these Anthropocene times because of fertilization of phosphorus and nitrogen for crop and animal production. One of the most dramatic cases in North America is the recent accelerated eutrophication of Lake Erie in the Laurentian Great Lakes. Also, we have lost, by some estimates, 50% of the world's wetlands in the 20th century and 90% of the wetlands in Ohio USA over the 19th and 20th centuries. We are proposing a serious analysis of an ecological engineering opportunity to restore parts of the former 400,000 ha (1 million acre) Great Black Swamp that was immediately southwest of Lake Erie in Ohio and is now one of the major sources of agricultural phosphorus to western Lake Erie through the Maumee River. Restoring and creating 20,000–40,000 ha (50,000–100,000 acres) or 5–10% of the original wetlands in the Black Swamp to optimize nutrient reduction could reduce phosphorus loading by 480–960 metric tons/year or 18–37% percent of the annual phosphorus loading by the Maumee River to Lake Erie.

A thorough investigation of this idea will first require physical (multi-year mesocosm experiments), mathematical, and business models to explore biogeochemical, hydrologic and economic feasibility and reliability. If this presents reasonable results, it would be followed by the creation of a small 400–1000 ha (1000–2500 acre) demonstration treatment wetland in the Black Swamp region to see if wetland performance will scale up as predicted with the mesocosm and mathematical models. Only after a decade of studies at these smaller scale models and a demonstration levels would the full-scale nutrient retention wetlands be implemented in the former Black Swamp. When completed, these treatment wetlands would cover about 10% of the Great Black Swamp region and could remove, with proper ecological engineering design, 40% or more of the phosphorus load from the Maumee River Basin now going into Lake Erie.

1. Introduction

Harmful algal blooms in western Lake Erie in North America's Laurentian Great Lakes for the past few years (Michalaka et al., 2013) and the toxic algae that caused Toledo Ohio to shut down the municipal water supply in August 2014 (Biello, 2014; Troy, 2014; Edwards, 2014) are symptomatic that there is something very wrong with the way we are managing our landscapes around vulnerable aquatic ecosystems.

Nutrients, especially phosphorus pouring into this shallowest (18-m average) portion of the shallowest Great Lake in seasonal and storm runoff from agricultural fields, are causing seasonal bursts in algal production with their accompanying problems of slimy aesthetics, dissolved oxygen depletion in bottom waters, fish kills, and toxicity. An Ohio Lake Erie Phosphorus Task Force (Ohio Department of Agriculture et al., 2013) has determined that excessive nutrients are "impacting an $11.5 billion tourism industry" on Lake Erie.

It is time to solve this problem and almost all agree on that. But most if not all the options being considered are limited and/or inconsequential. To solve ecological problems of this scale, large-scale ecological solutions are needed. I am proposing that restoration of some portion of the Great Black Swamp, which as late as the early 19th century was a 4000 km^2 (1 million acre) wetland that formed a western extension of the western basin of Lake Erie, as a programmed and precisely designed ecological engineered series of wetlands that would serve as nutrient sinks to protect Lake Erie while recycling the captured nutrients back to agriculture.

2. The Great Black Swamp

A vast wetland of Midwestern USA that has ceased to exist was and is referred to as the "Great Black Swamp" or "Black Swamp" in what is now northwestern Ohio. It has been brought to the attention of wetland

* Corresponding author at: Everglades Wetland Research Park, Florida Gulf Coast University, 4940 Bayshore Drive, Naples, FL 34112, USA.
E-mail address: wmitsch@fgcu.edu.

http://dx.doi.org/10.1016/j.ecoleng.2017.08.040
Received 9 August 2017; Received in revised form 22 August 2017; Accepted 24 August 2017
0925-8574/

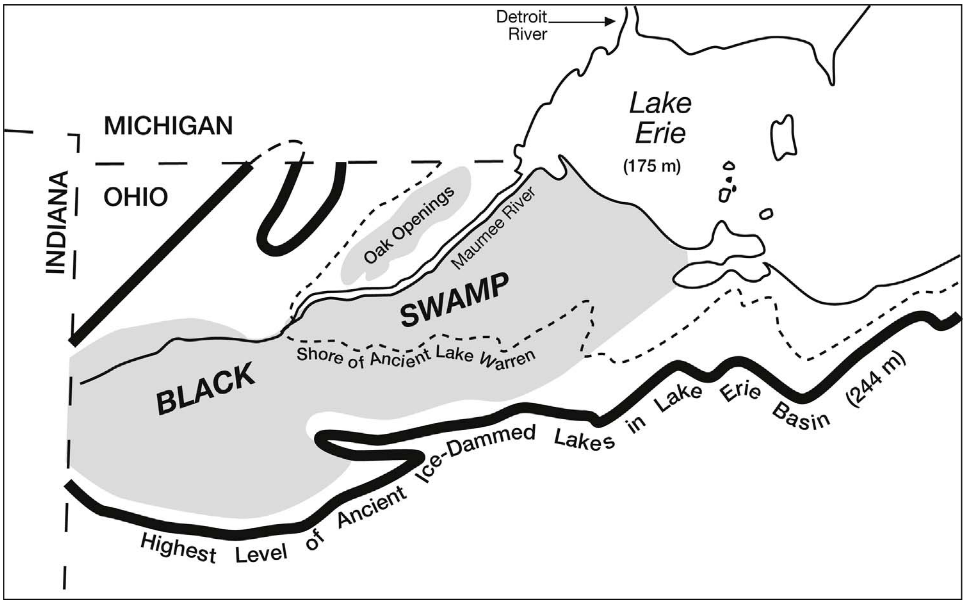

Fig. 1. The Great Black Swamp as it probably existed 200 years ago in northwestern Ohio (From Forsyth, 1960). Essentially none of this 4000-km^2 wetland remains. Numbers on map indicate land and lake elevation in m above sea level.

students and researchers for the last 25 years in the last 4 editions of the Wetlands textbook (Mitsch and Gosselink, 1993 through Mitsch and Gosselink, 2015). The Great Black Swamp (Fig. 1) was once a combination of marshland and forested swamps covering a vast area of the flat post-glacial lake plains southwest of Lake Erie that stretched from current Toledo Ohio to Fort Wayne, Indiana. It extended about 160 km and covered an estimated area of 4000 km^2. The Black Swamp was named for the rich, black muck that developed in areas where drainage was poor because of several ridges that existed perpendicular to the direction of the flow to the lake. There are numerous accounts of the difficulty that early settlers and armies (especially during and after the War of 1812) had in negotiating this region, and few towns of significant size have developed in the location of the original swamp. One published account of travel through the region in the late 1700s suggested that "man and horse had to travel mid-leg deep in mud" for three days just to cover only 50 km (Kaatz, 1955).

As with many other wetlands in Midwestern USA, state and federal drainage acts led to the rapid drainage of this wetland, until little of it was left by the beginning of the twentieth century. In its peak years of drainage, there were more than 50 factories in this region of Ohio manufacturing clay tiles from the readily available clay soil in the region. Most of the drainage occurred from 1870 to 1920 that "completely erased the Black Swamp" (Levy, 2017; Fig. 2).

As described by Levy (2017), the strong belief of maintaining the drained landscape prevails even to today: "Among the descendants of the settlers who conquered the Black Swamp, drainage is viewed as sacred, while wetland restoration borders on the profane. In terms of water quality, a prime place to create wetlands would be where they intercept the flow of polluted water in farm ditches. That could cause water to back up and flood the fields, however, and it is forbidden under Ohio's ditch laws, which have changed little since 1859."

Only small examples of these extensive interior wetlands and Lake Erie coastal marshes remain of the original western Lake Erie wetlands. Goll Woods Nature Preserve, a 130-ha forest island in an otherwise uninterrupted sea of agriculture fields is the closest remembrance of what the Black Swamp looked like (Fig. 3). As poetically described by Levy (2017): "Standing in the heart of Goll Woods, immersed in the aroma of dry mud and fallen leaves, it's easy to conjure the wild past. An expanse of ancient trees stretched for a million wet acres, interrupted only by stands of tall marsh grass. The only residents were deer, elk, wolf, cougar, badger, beaver, bear, muskrat, and an astounding abundance of waterfowl. Today Goll Woods stands amid endless soybean and corn fields, a ghostly remnant of a former wilderness."

3. Solving Lake Erie harmful algal blooms

3.1. The phosphorus problem for western Lake Erie

The Western Basin of Lake Erie receives 60% of the total phosphorus and 68% of the dissolved reactive phosphorus that enters Lake Erie (Scavia et al., 2014) almost all from the Maumee River and the Detroit River (Fig. 4). But the Detroit River is high flow with low concentrations of phosphorus while the Maumee River delivers lower flow but higher concentrations of phosphorus (Scavia et al., 2017). This has led managers to focus efforts to mitigate the harmful algal blooms in western Lake Erie on controlling phosphorus coming from the Maumee River Basin and particularly from the agricultural fields that drain the former Black Swamp.

The Maumee River watershed is 1.7 million ha of the 2.9 million ha draining to the western basin and "the severity of HABs in the western basin is highly correlated with Maumee River loads" (Ohio Department of Agriculture et al., 2013). The Ohio Department of Agriculture et al. (2013) recommended that to minimize the Lake Erie algal blooms to acceptable levels, the March-June Maumee River total phosphorus loads be less than 800 metric tons, 37% lower than the 2007–12 loading rate. A more recent goal of 40% reduction of March–June dissolved reactive phosphorus and total phosphorus discharges from the Maumee River was recommended (Scavia et al., 2016, 2017) to 186 and 860 metric tons/year respectively. Scavia et al. (2016), in a multi-institutional landscape modeling report published at the University of Michigan, concluded that current programs, mostly agricultural best management practices, do not have "sufficient funding or policies in place that enable targeting of the best practices in the right places to support implementation at the necessary scale to reduce phosphorus export." Curiously their last simulation was for wetlands and buffer strips combined and they found that wetlands and buffer strips could