Economic consequences of cyanotoxin health risks

… in Lake Erie

Frank Lupi

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Michigan State University

MICHIGAN STATE UNIVERSITY

Myriad economic impacts of Lake Erie Cyano HABs

- Water treatment and monitoring
- Water closure costs (Toledo)
- Clean-up & remediation
- Commercial fishing
- Charter fishing
- Recreational fishing
- Recreational (non-fishing) boating
- Beach use
- Other recreation & tourism
- Property values
- Health impacts

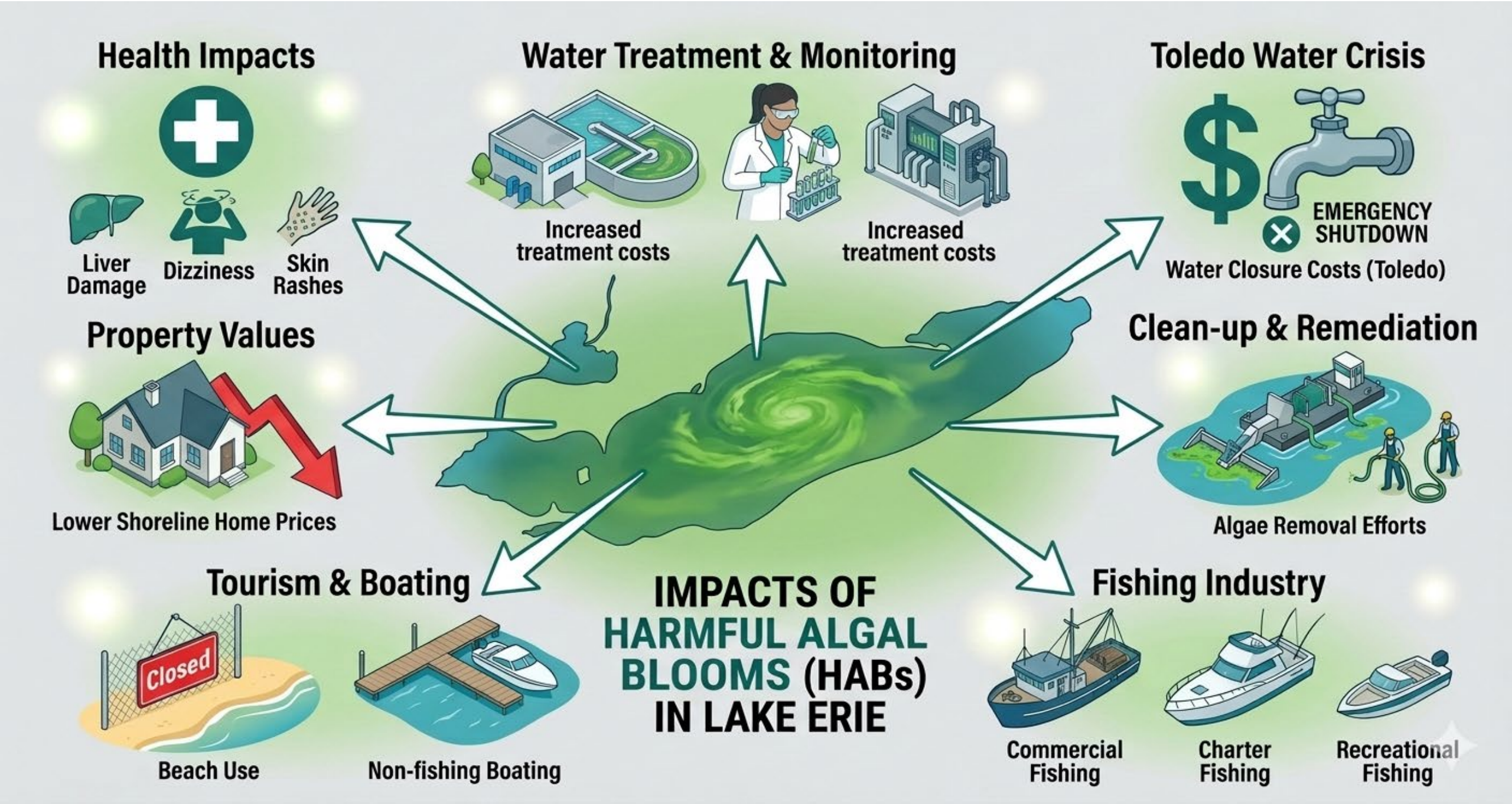


Image by “Nano Banana 2”

HARMFUL ALGAL BLOOMS AND ASSOCIATED ILLNESSES, 2016–2021

1,272
Harmful algal blooms

666
Human illnesses

4,375+
Animal illnesses & deaths

Data from 25 states reporting to CDC's national harmful algal bloom surveillance system—the One Health Harmful Algal Bloom System

104
Outbreaks from contaminated seafood

Data from 50 states, Washington D.C., and Puerto Rico reporting to CDC's National Outbreak Reporting System

Source: CDC 2023

Health impacts of HABs

Direct health care costs

Lost work and/or income

Disutility of any illness or health effects

Expenditures on prevention, monitoring, advisories

& Impacts on animals & pets

Health impacts

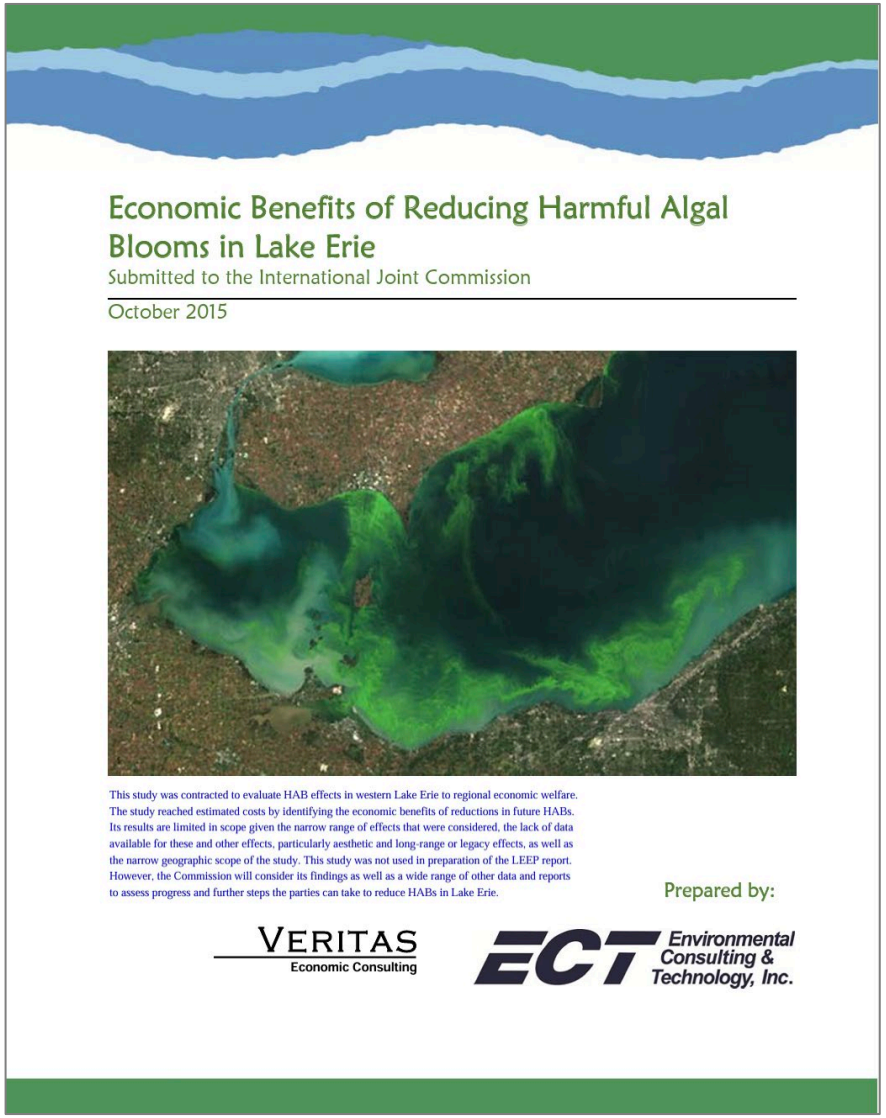
Estimated HAB health impacts have a wide range: $86 to $14,600 per illness

Kouakou & Poder J Water Health, 2019

Hoagland et al. Estuaries, 2002

Some Lake Erie background

Relatively comprehensive "back-of-the-envelop" estimates of full economic costs of the 2011 and 2014 HAB events



Economic Benefits of Reducing Harmful Algal Blooms in Lake Erie

Submitted to the International Joint Commission

October 2015

This study was contracted to evaluate HAB effects in western Lake Erie to regional economic welfare. The study reached estimated costs by identifying the economic benefits of reductions in future HABs. Its results are limited in scope given the narrow range of effects that were considered, the lack of data available for these and other effects, particularly aesthetic and long-range or legacy effects, as well as the narrow geographic scope of the study. This study was not used in preparation of the LEEP report. However, the Commission will consider its findings as well as a wide range of other data and reports to assess progress and further steps the parties can take to reduce HABs in Lake Erie.

Prepared by:

VERITAS Economic Consulting

ECT Environmental Consulting & Technology, Inc.

IJC report, 2015

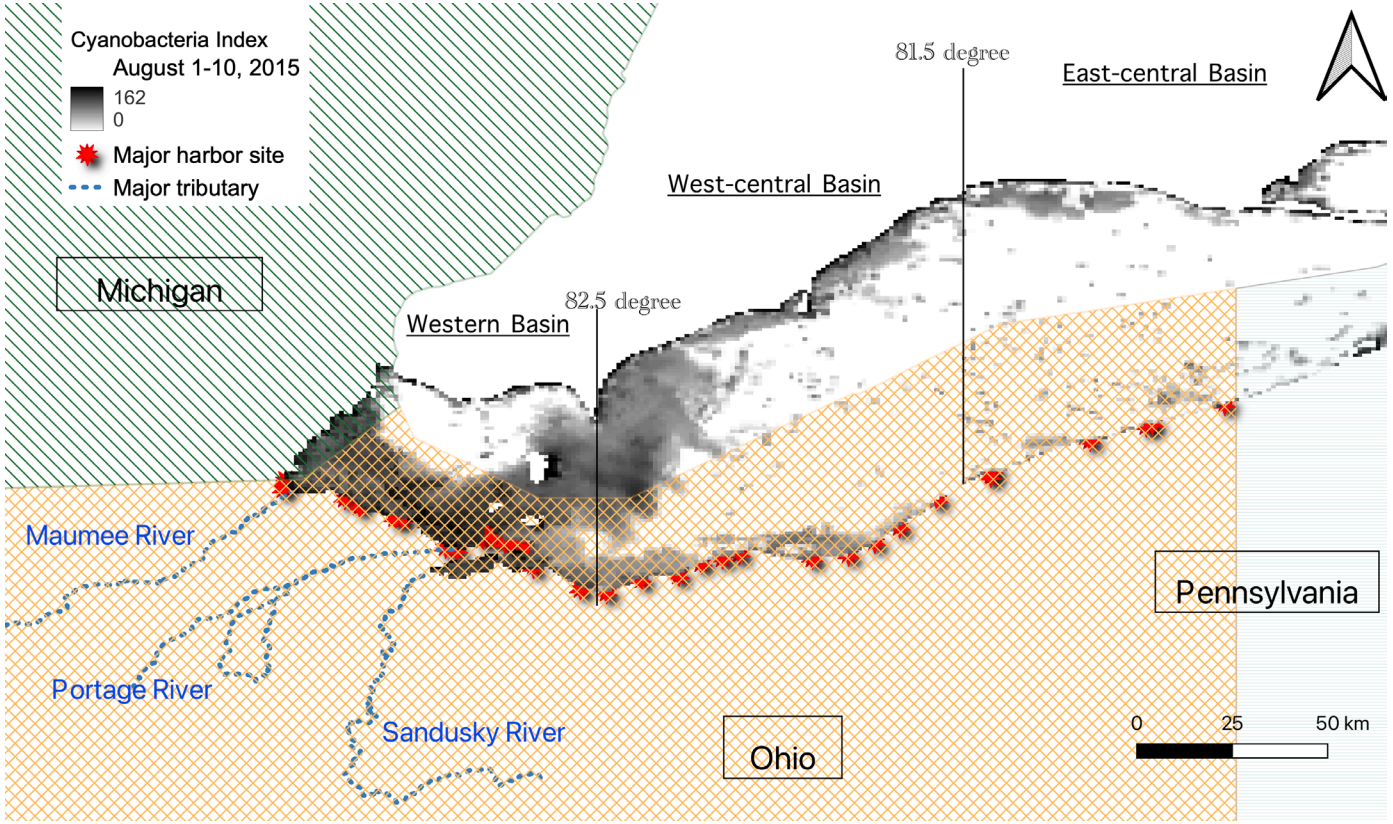
Aside: Economic damages for Lake Erie recreational boat fishery

Paper under review:

Waters of Change:
Spatiotemporal Recreational Fishing Welfare Losses from Recurring HABs on Lake Erie

Y. Wu, F. Lupi & B. Sohngen

Uses long term data on month & site of boat fishing trips from OH DNR to link HABs and trips.



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Economic damages of water quality warnings in the Great Lakes

Greg Boudreaux[1,2], Frank Lupi[2] & Brent Sohngen[3]

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[1] U.S. Army Corps of Engineers, Chicago District (now UC Davis)
[2] Michigan State University
[3] *The* Ohio State University

SECTIONS

The New York Times

ENVIRONMENT

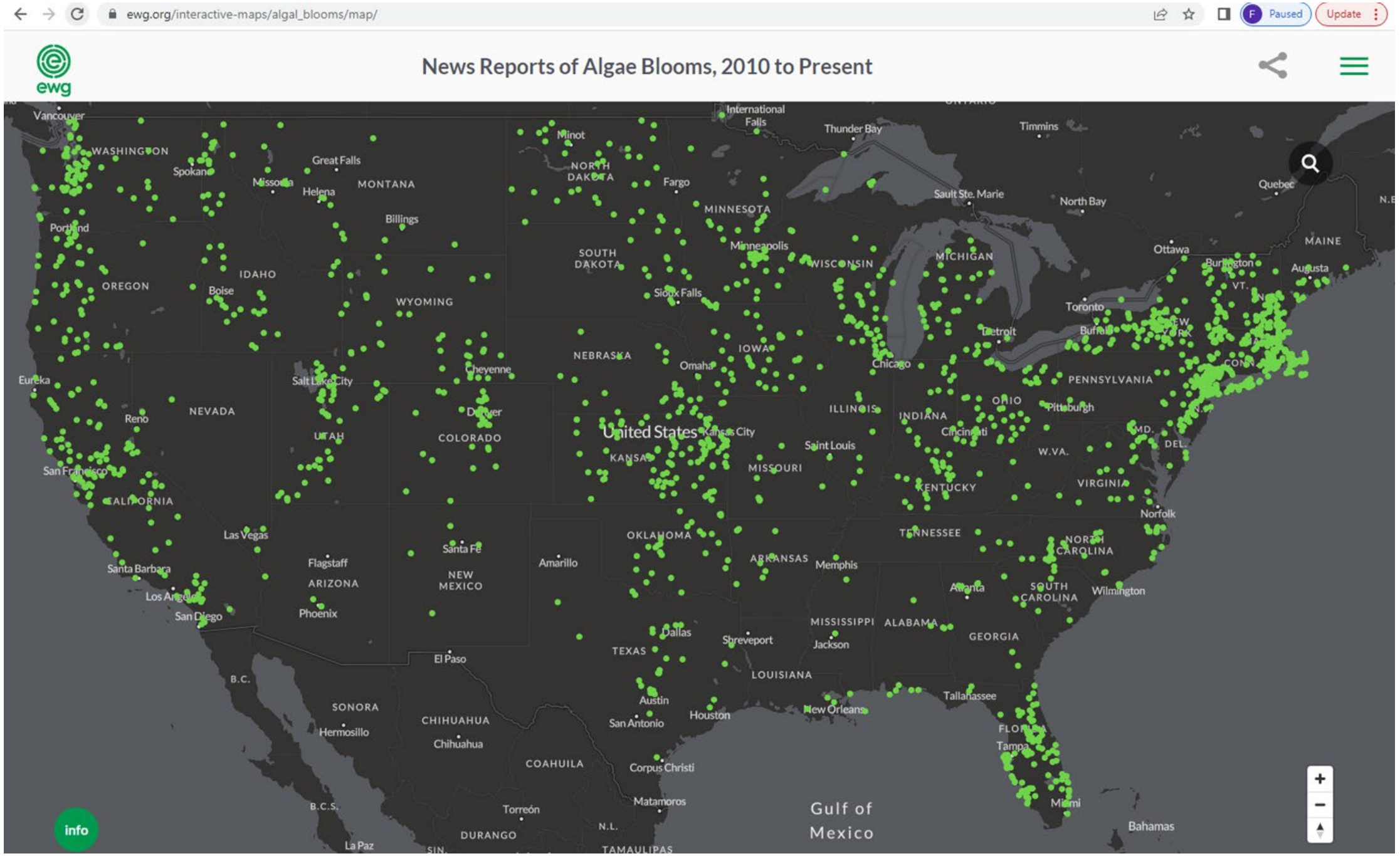
SHARE

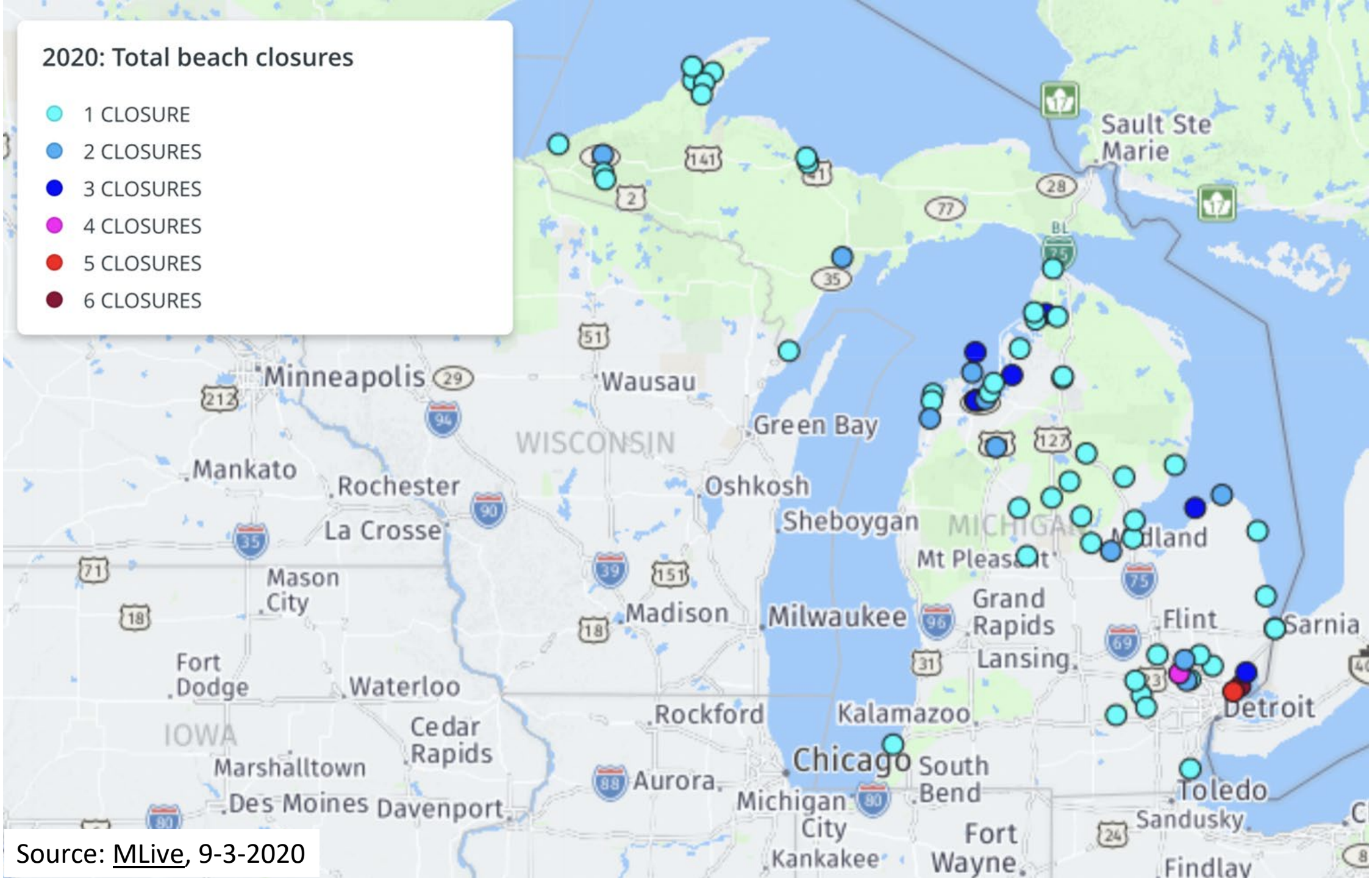
Miles of Algae Covering Lake Erie

By JUGAL K. PATEL and YULIYA PARSHINA-KOTTAS OCT. 3, 2017

A potentially harmful algae bloom covered more than 700 square miles in the western basin of Lake Erie last week, turning the lake bright green and alarming residents and local officials.

Source: Landsat 8


ewg.org/interactive-maps/algal_blooms/map/
Paused
Update
ewg
News Reports of Algae Blooms, 2010 to Present
Vancouver
WASHINGTON
Spokane
Great Falls
Missoula
Helena
MONTANA
Billings
Portland
IDAHO
OREGON
Boise
WYOMING
Minot
NORTH DAKOTA
Fargo
MINNESOTA
SOUTH DAKOTA
Minneapolis
Sioux Falls
International Falls
Thunder Bay
Timmins
Sault Ste. Marie
North Bay
Quebec
MAINE
Ottawa
Burlington
Augusta
VT.
WISCONSIN
MICHIGAN
Toronto
Detroit
Buffalo
NEBRASKA
Omaha
IOWA
Chicago
Cheyenne
Salt Lake City
Eureka
Reno
NEVADA
UTAH
COLORADO
Denver
United States
Kansas City
KANSAS
Saint Louis
MISSOURI
ILLINOIS
INDIANA
OHIO
Cincinnati
Pittsburgh
PENNSYLVANIA
MD.
DEL.
W.VA.
KENTUCKY
VIRGINIA
Norfolk
San Francisco
CALIFORNIA
Las Vegas
Santa Fe
Flagstaff
ARIZONA
NEW MEXICO
Amarillo
OKLAHOMA
TENNESSEE
ARKANSAS
Memphis
NORTH CAROLINA
Santa Barbara
Los Angeles
San Diego
Phoenix
Atlanta
SOUTH CAROLINA
Wilmington
MISSISSIPPI
ALABAMA
GEORGIA
Dallas
Shreveport
Jackson
TEXAS
El Paso
LOUISIANA
B.C.
SONORA
Hermosillo
CHIHUAHUA
Chihuahua
Austin
San Antonio
Houston
New Orleans
Tallahassee
Tampa
COAHUILA
Corpus Christi
Matamoros
Torreón
B.C.S.
DURANGO
N.L.
TAMAULIPAS
La Paz
Gulf of Mexico
Miami
Bahamas
info



Source: MLive, 9-3-2020

mlive.com/news/2022/08/1

News

14 beaches across M have contaminatio

Updated: Aug. 05, 2022, 1:40 p.m. | Published:

By Justine Lofton | jlofton@mlive.com

As the weekend approaches, there or under contamination advisories or questionable – for human conta of opportunities to take a dip in the

13abc.com/2022/06/21/maumee-ba...

Paused Update

13abc ACTION NEWS
WTVG • TOLEDO • OHIO

77°
Toledo, OH

News Weather Back To School

Maumee Bay State Park swimming areas under Bacteria Contamination Advisory

Children, the elderly and anyone in ill health or who have weakened immune systems are advised not to swim. (WTVG)

By Jake Pietrasz

Published: Jun. 21, 2022 at 12:37 PM EDT

TOLEDO, Ohio (WTVG) - The Ohio Department of Health has posted a Bacteria Contamination Advisory for the swimming areas at Maumee Bay State Park.

ODH posted the advisory on June 21 at 10 a.m. According to the ODH website, a Bacteria Contamination Advisory is posted when the level of bacteria in the water has

onroe County – contamination
n is listed as “other” from an

Monroe County – contamination
n is listed as “other” from an

emorial Park Beach, Macomb
lue to high bacteria levels from
fth closure for the beach so far
s so far. The beach has been
four times for a total of 29 days.
c County Park, Arenac County –
g. 3 due to high bacteria levels

air Metropark Beach, Macomb
lue to high bacteria levels from
vas closed for the same reason

Research questions

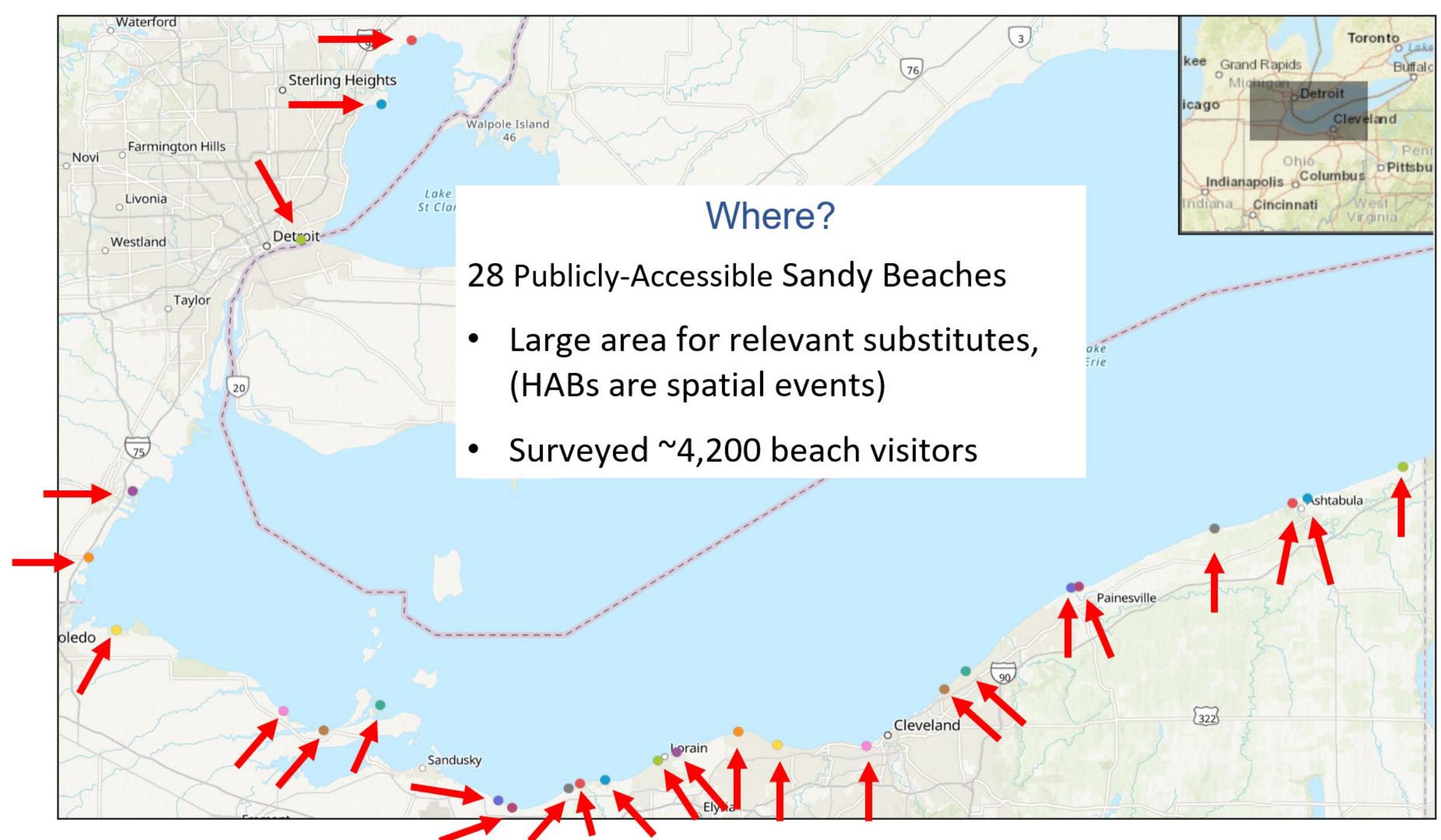
- What are the economic losses to beachgoers of HAB and *E. coli* warnings?

  How do trips respond to warnings?

- Do recreational losses end when the warnings end?

Contributions

- Adds to small GL beach valuation lit. (Murray et al. 2001; Lupi et al. 2022)
- Most economic lit. HAB & bacterial work focuses on foreign and/or saltwater settings (L'Ecuyer-Savageau et. al 2010; Taylor & Longo 2010; Marsh 2012; Kosenius 2018)
- Existing lit. uses beach closings as a proxy for warnings (Palm-Forster et al. 2016, Wolf et al. 2019) but beaches are often not closed
- We consider lagged effects of past warnings



Where?

28 Publicly-Accessible Sandy Beaches

- Large area for relevant substitutes, (HABs are spatial events)
- Surveyed ~4,200 beach visitors

Intercept and Follow-up Surveys

Intercept survey

N = 4,239

86% resp rate

- Intercept: followed a stratified sampling plan (month, weekday/weekend, region strata), randomized shift times and beach sequences (Taurangeau et al. 2017)
  - Collected time on site, purpose, party size, Zip code, age, education, E-mail

Intercept and Follow-up Surveys

Intercept survey

N = 4,239

86% resp rate

Online follow-up

N = 1,067

47% resp rate

- Intercept: followed a stratified sampling plan (month, weekday/weekend, region strata), randomized shift times and beach sequences (Taurangeau et al. 2017)
  - Collected time on site, purpose, party size, Zip code, age, education, E-mail

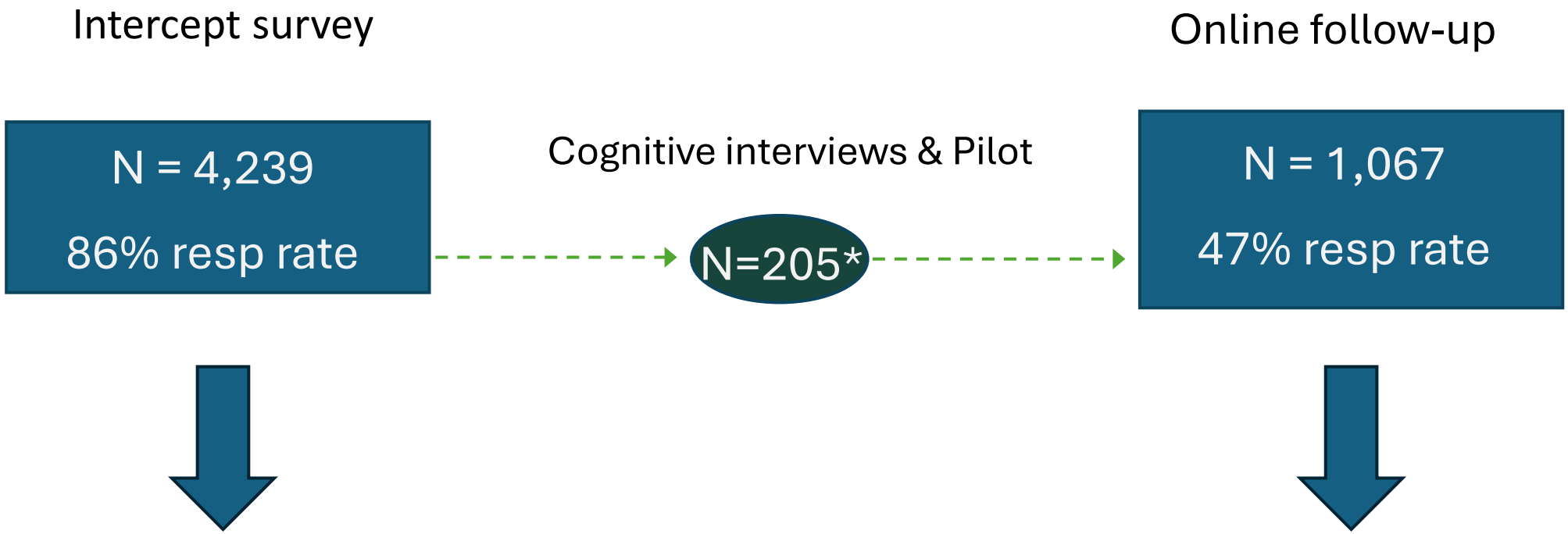
- Follow-up: developed following best practices for stated preferences (Johnston et al. 2017)

Intercept and Follow-up Surveys

* Survey testing with eligible beachgoers

- N=14 via focus groups
- N=15 via one-on-one cognitive interviews
- N=176 pilot via MTurk using 2-stage survey

Intercept and Follow-up Surveys



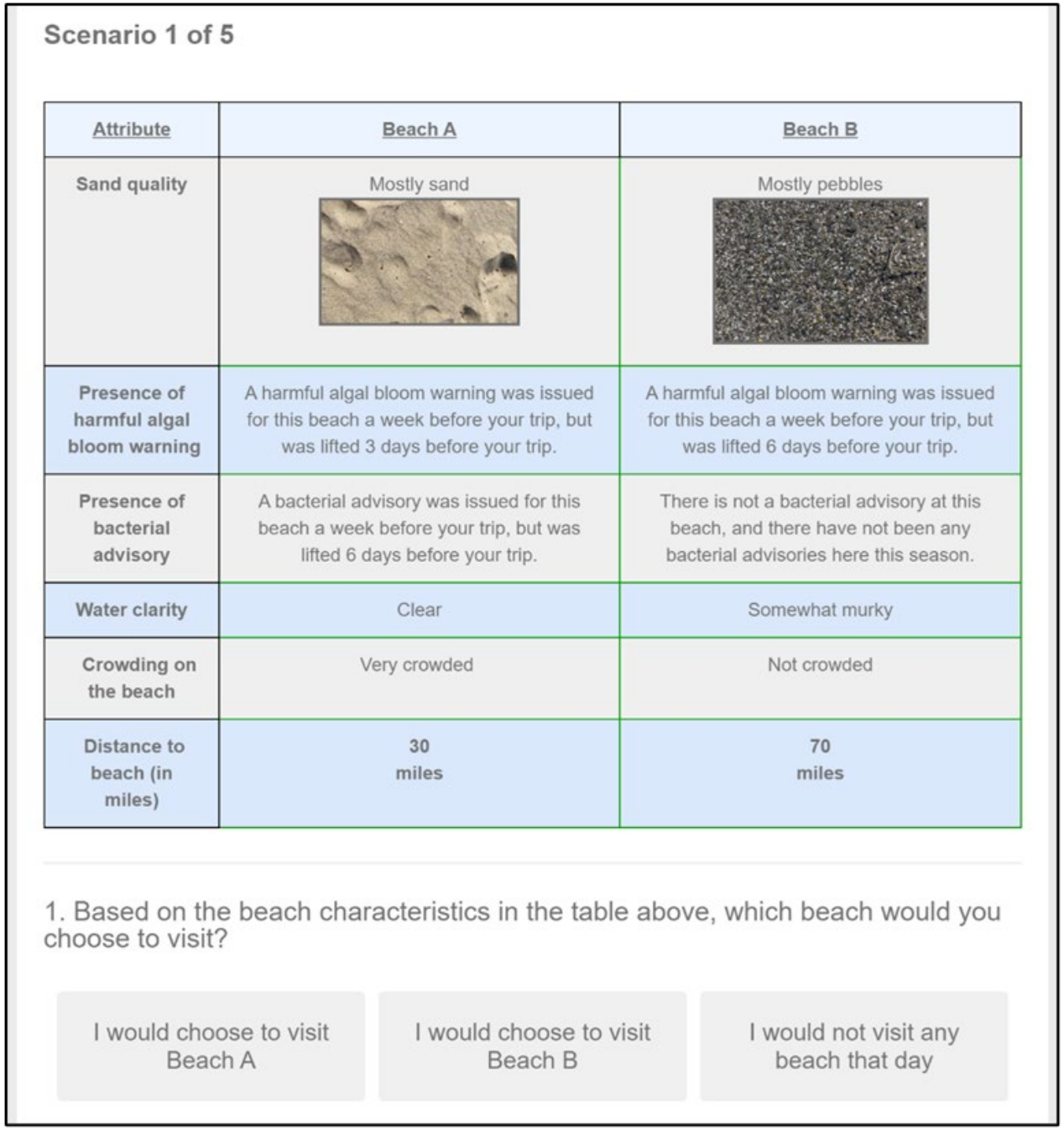
Beach visits economic demand system

Choice experiment for demand shift

Choice Experiment (trade-off questions)

Online follow-up survey

- 5 trade-offs per respondent
- Vary the attributes across questions & respondents
- Developed using multiple rounds of cognitive interviews & pilot survey following best practices (Johnston et al. 2017)



Scenario 1 of 5

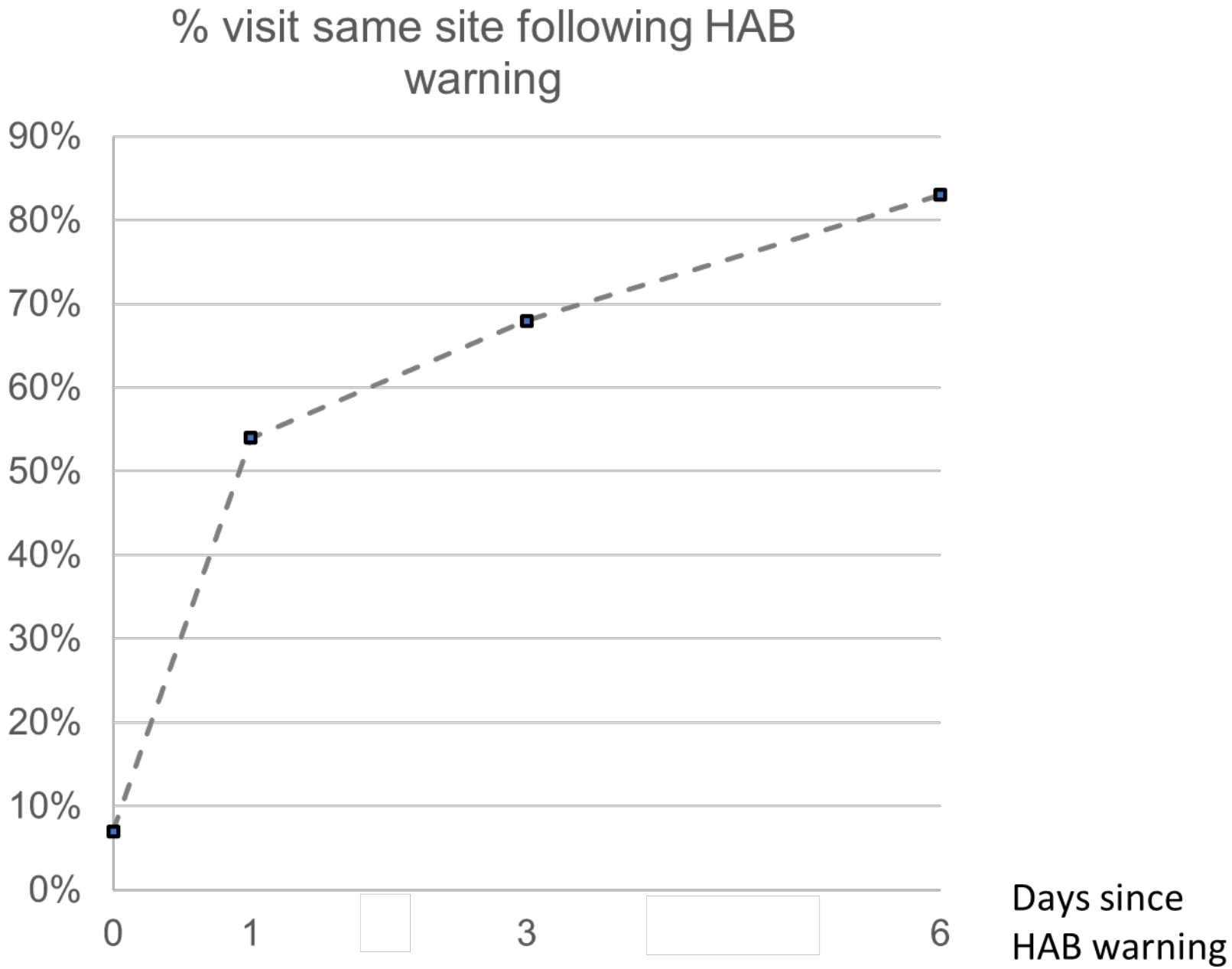
Attribute	Beach A	Beach B
Sand quality	Mostly sand	Mostly pebbles
Presence of harmful algal bloom warning	A harmful algal bloom warning was issued for this beach a week before your trip, but was lifted 3 days before your trip.	A harmful algal bloom warning was issued for this beach a week before your trip, but was lifted 6 days before your trip.
Presence of bacterial advisory	A bacterial advisory was issued for this beach a week before your trip, but was lifted 6 days before your trip.	There is not a bacterial advisory at this beach, and there have not been any bacterial advisories here this season.
Water clarity	Clear	Somewhat murky
Crowding on the beach	Very crowded	Not crowded
Distance to beach (in miles)	**30 miles**	**70 miles**

1. Based on the beach characteristics in the table above, which beach would you choose to visit?

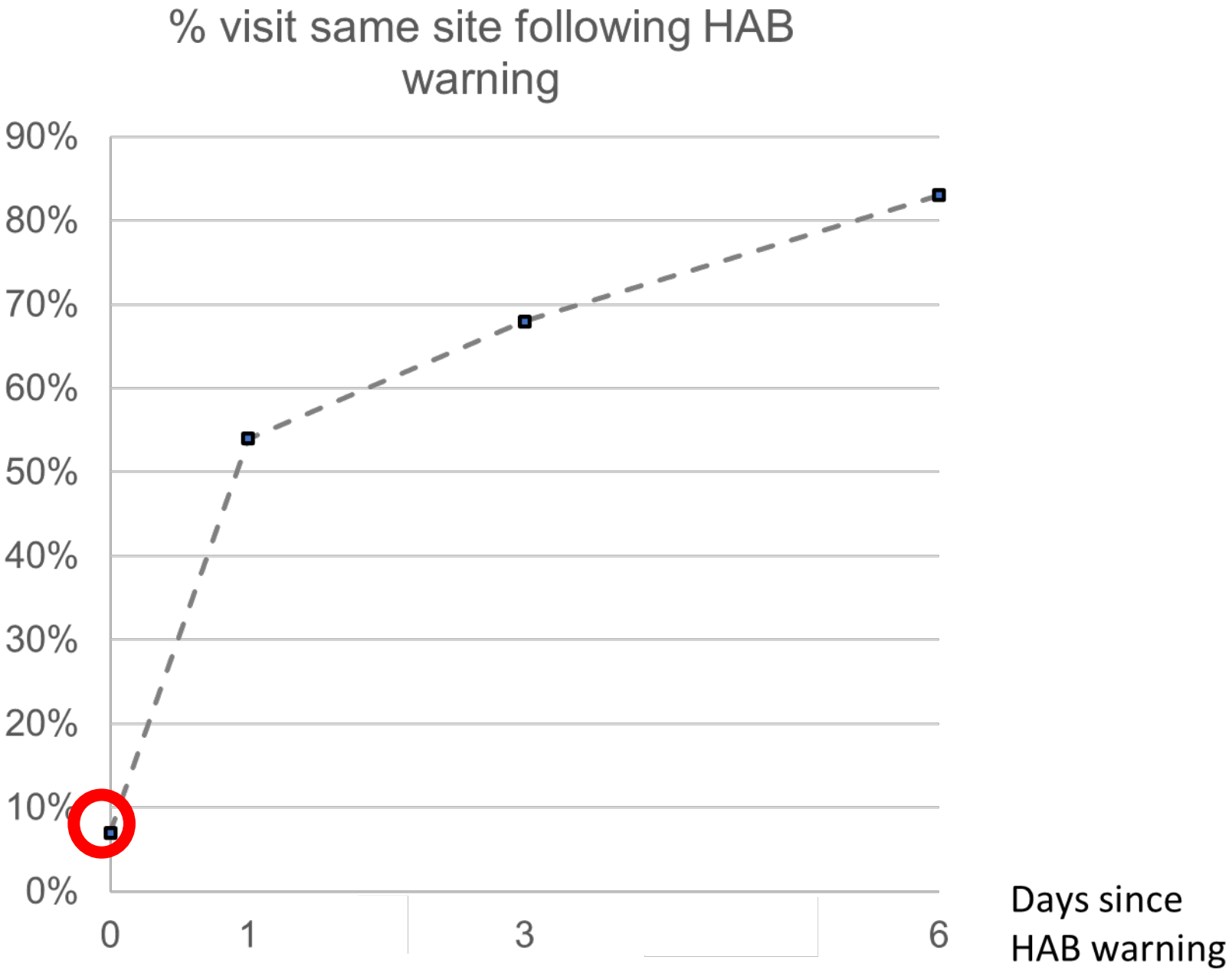
I would choose to visit Beach A

I would choose to visit Beach B

I would not visit any beach that day

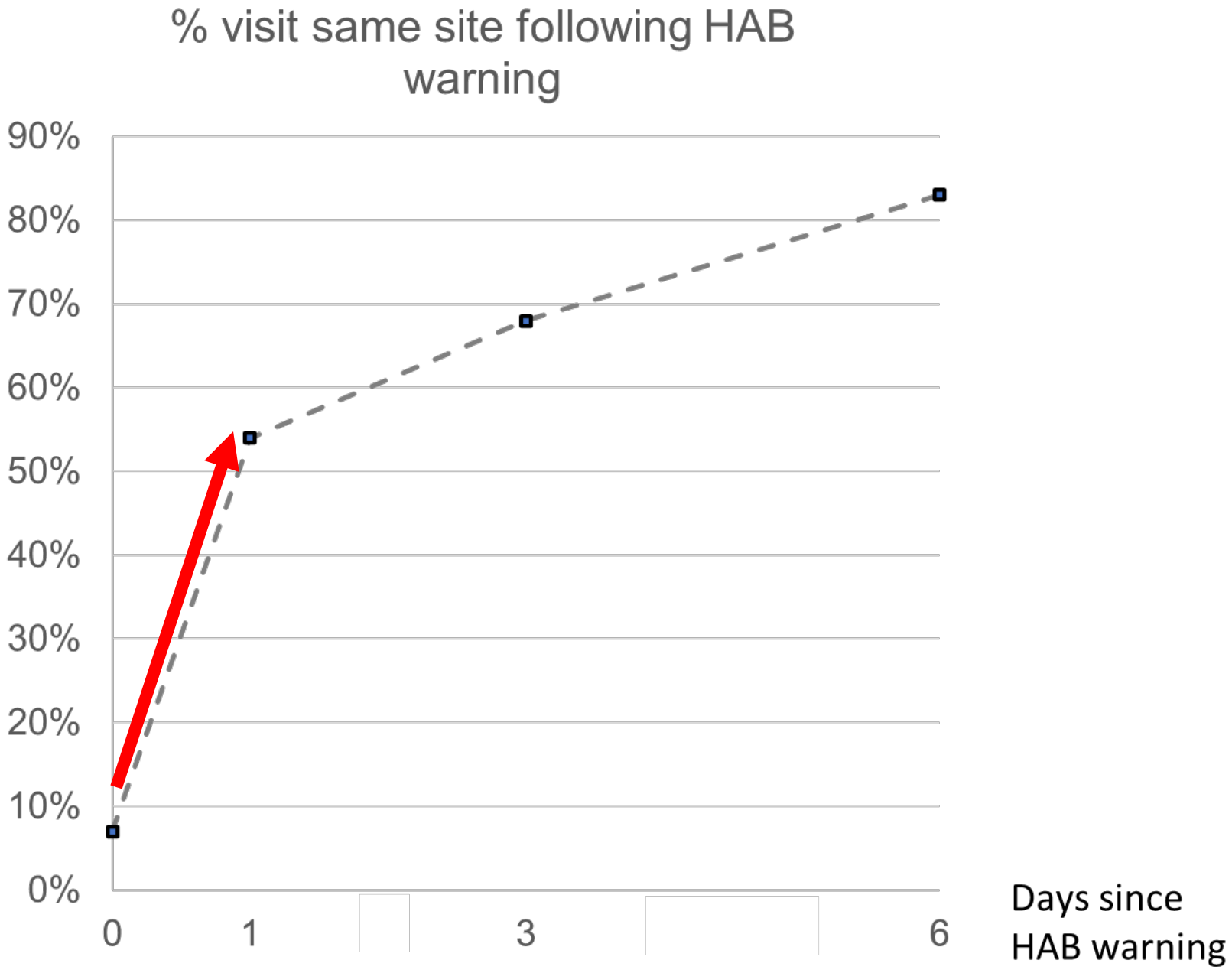

% visit same site following HAB warning
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
3
6
Days since HAB warning

Few visit during a HAB, but some do.



Few visit during a HAB, but some do.

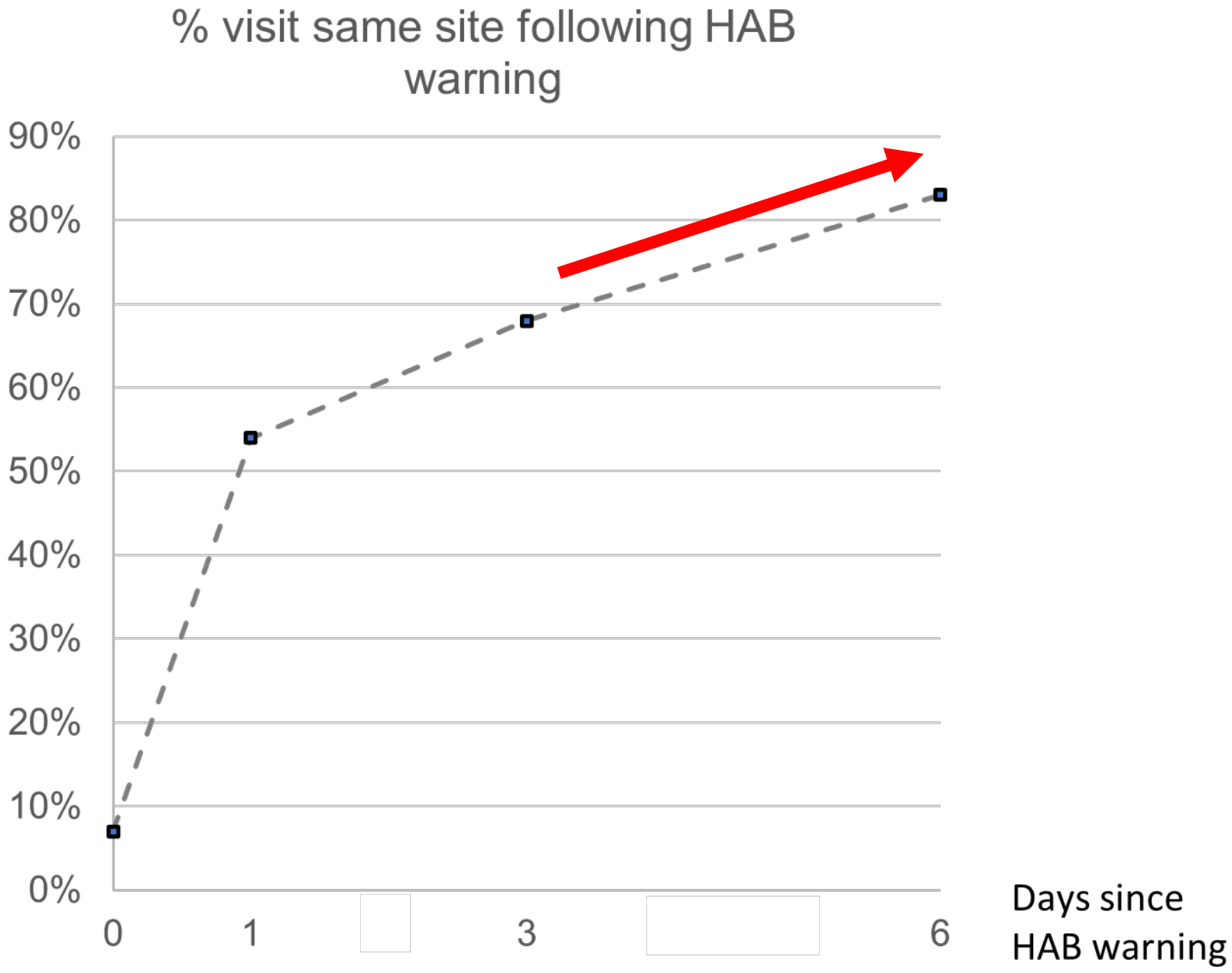
1 day after HAB warning is lifted, visitation rises, but not fully.



Few visit during a HAB, but some do.

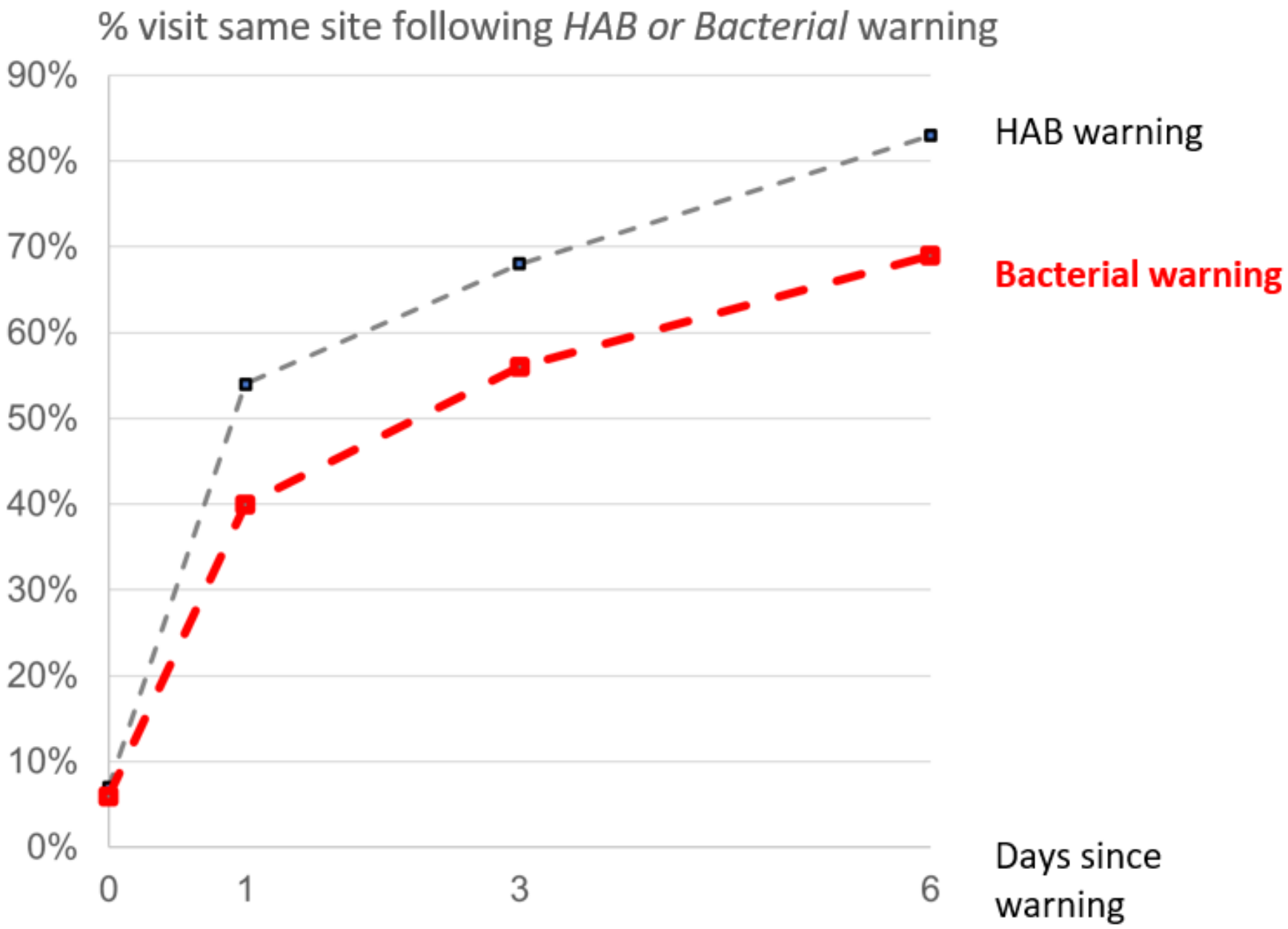
1 day after HAB warning is lifted, visitation rises, but not fully.

After 6 days visits are mostly, but not fully, recovered



After lifting a **bacterial** warning:

- visitation pattern is similar to HABs
- exhibits slower recovery after warning



Results mean…

- Significant aversion to sites with HAB or Bacterial warning
- Aversion persists, but declines with time since warning lifted
- Ignoring stigma effect understates losses by 33% to 40%

Ecological Economics 204 (2023) 107653

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Measuring beachgoer preferences for avoiding harmful algal blooms and bacterial warnings

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[b] Department of Agricultural, Food, and Resource Economics, Michigan State University, East Lansing, MI, USA
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ARTICLE INFO

Keywords:
Water quality
Choice experiment
Harmful algal bloom
Bacterial contamination
Stated preference
Great Lakes

ABSTRACT

This paper estimates beachgoers' preferences for beach quality, including avoidance of harmful algal blooms and bacterial warnings. Following a stratified random sampling schedule, data was collected via interviews conducted at 28 public beaches from Eastern Ohio to Northern Lake St Clair. Randomly selected visitors were interviewed and sent a follow-up choice experiment survey, which measured preferences for beach attributes. We find the average respondent is willing to drive 260 and 266 miles to avoid sites with either current HAB or bacterial warnings, and find a negative stigma effect that remains at least 6 days post-warning. While respondents' aversion to active HAB and bacterial warnings are not statistically different, this aversion decreases more slowly after a bacterial warning; respondents are willing to drive 77 miles to avoid a site with a bacterial warning lifted 6 days earlier, but only 31 miles to avoid a site with a HAB warning lifted 6 days earlier. To test our findings' validity, we used the choice model estimates to simulate responses to contingent behavior questions from the follow-up. Although framed differently, the elicitation formats yield concordant findings. Results indicate that cost-benefit analysis which doesn't evaluate the stigma effect of recently-lifted warnings may understate their costs.

1. Introduction

Global water resources are impacted by a combination of human management actions and climate change-induced extreme weather patterns. Anthropogenic warming directly exacerbates the frequency and intensity of precipitation events (Fischer and Knutti, 2015) leading to an increase in the quantity of agricultural and urban stormwater runoff (Labat et al., 2004). Rising global water temperatures in both fresh and saltwater ecosystems (Kaushal et al., 2010), worsen both surface and groundwater pollution from the existing large influxes of runoff from human industrial and agricultural processes (Hamid et al., 2020; Hrdinka et al., 2012). Chief drivers of many of these pollution events are "macro-pollutants" such as nitrogen and phosphorous, as well as high concentrations of bacteria and other waterborne pathogens (Schwarzenbach et al., 2010; Zimmerman et al., 2008). Climate change has the potential to cause increased loadings of both phosphorous and

Under certain environmental conditions, nutrient loadings contribute to cyanobacteria growth, which in turn contributes to the growth of harmful algal blooms (Heisler et al., 2008; Lewitus et al., 2012). HABs have been observed in all 50 US states (EPA) and are a significant and growing problem worldwide (Anderson, 2012). Using satellite data of 71 lakes around the world, researchers found that in 68% of these lakes, peak summertime bloom intensity has been steadily increasing since the 1980s (Ho et al., 2013). The growth of cyanobacteria in waterways can produce toxins known as microsystins, which cause liver damage, gastrointestinal illness, and skin irritation for people in contact with them (NIEHS (National Institute of Environmental Health Sciences, U.S. Department of Health and Human Services), 2020), and they have severe ecological impacts on bodies of water, such as hypoxic "dead zones" that deplete oxygen which nourishes aquatic wildlife (NOAA (National Oceanic and Atmospheric Administration), 2020). Fish or shellfish that are not killed by this lack of oxygen and

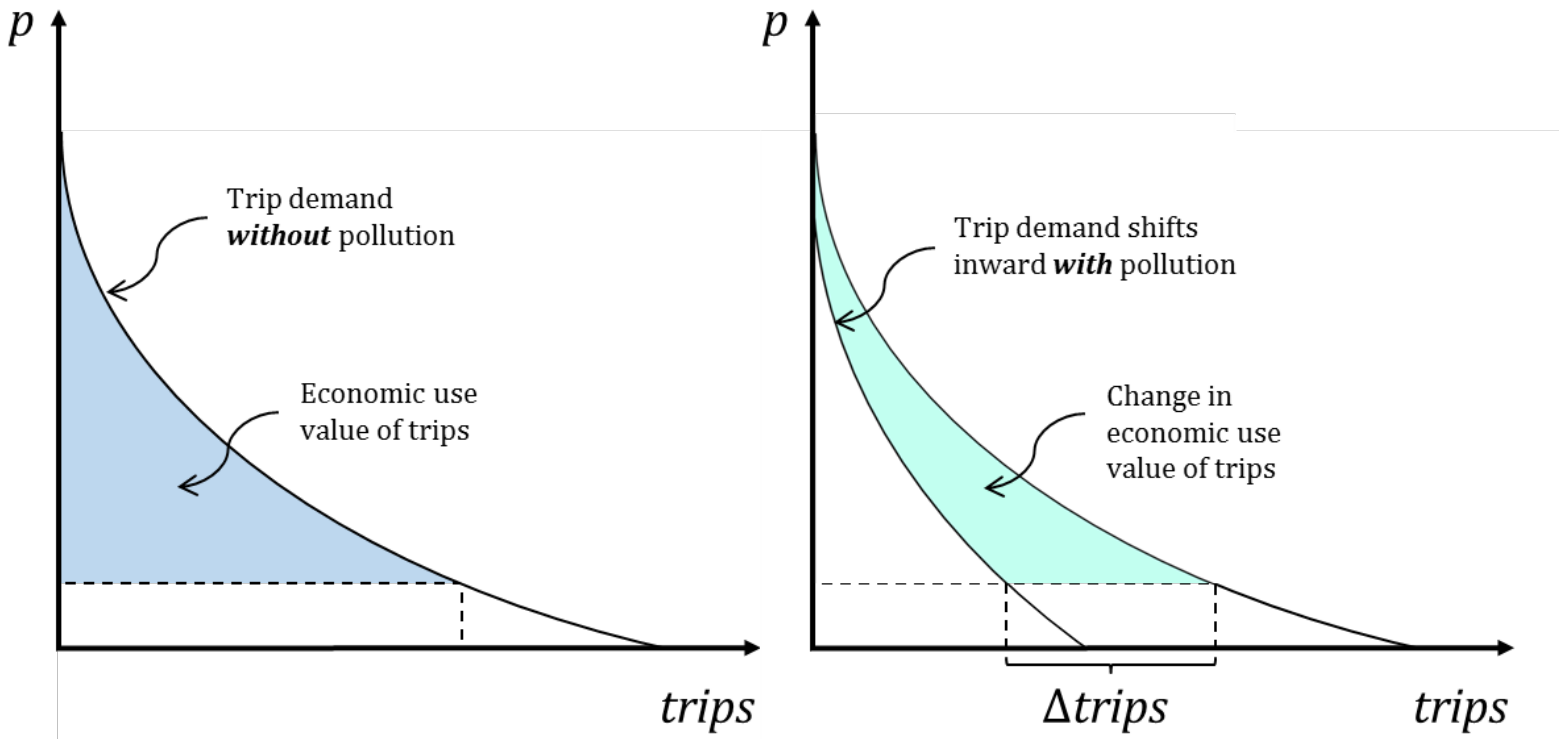
Part 2

Trips are affected ... but what about the economic losses?

Contact Lupi@msu.edu for draft paper

Economic method: Estimated beach visitation demand models for each of the 28 beaches

- Demand models allow us to quantify benefits to beachgoers
- Warnings shift demand curves
- Fewer trips means lost value to beachgoers
  &
  lost tourism revenues



Demand system: Baseline trips from intercept survey

Pro: Considered more reliable than “off-site” recall surveys (English et al. 2018; Tourangeau et al. 2017; Leggett 2017)

Con: On-site sampling is endogenous sampling (Englin and Shonkwiler 1995, Moeltner and Shonkwiler 2005, Landry et. al 2016, Hindsley et. al 2011)

Solution: Use intercept design weights to estimate trips from each origin zip to each site (von Haefen et al. 2022; Tanner and Lupi, 2023)

- 999 origin zips, 28 sites

Go from on-site sample weights to trips

- Trip estimation using design weights (inverse probabilities of intercepting person *i*) from sampling plan (Leggett 2017).

$$w_{hij} = \frac{N_h}{n_{jh}} \frac{M_i}{\tilde{d}} \frac{\overline{c_{hij}}}{K_{hij}} P_{rec,h}$$

Share of days at site *j* sample in stratum *h*

Share of time visitor on beach

Share of visitors interviewed at *j* in *h*

Share of people there for recreation

Baseline demand model specification

- Repeated Nested Logit with 29 alternatives, 28 sites, *j*, and "No trip", *j*=0

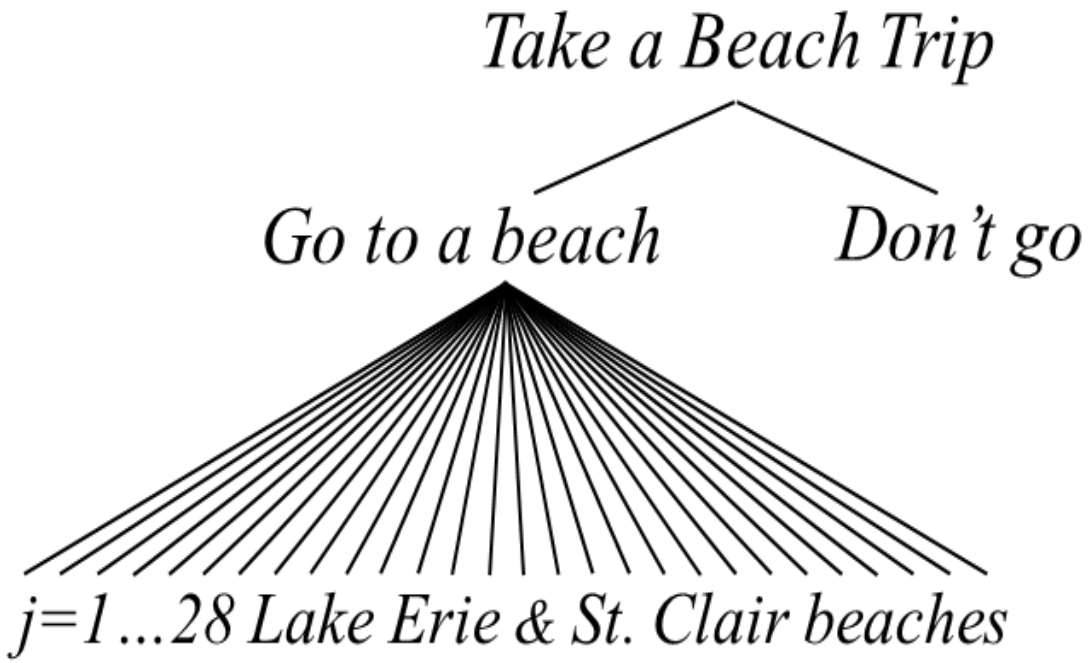
- Site Utility$_{zj}$ = f(travel costs$_{zj}$, fixed effect$_j$, ε_{zj})

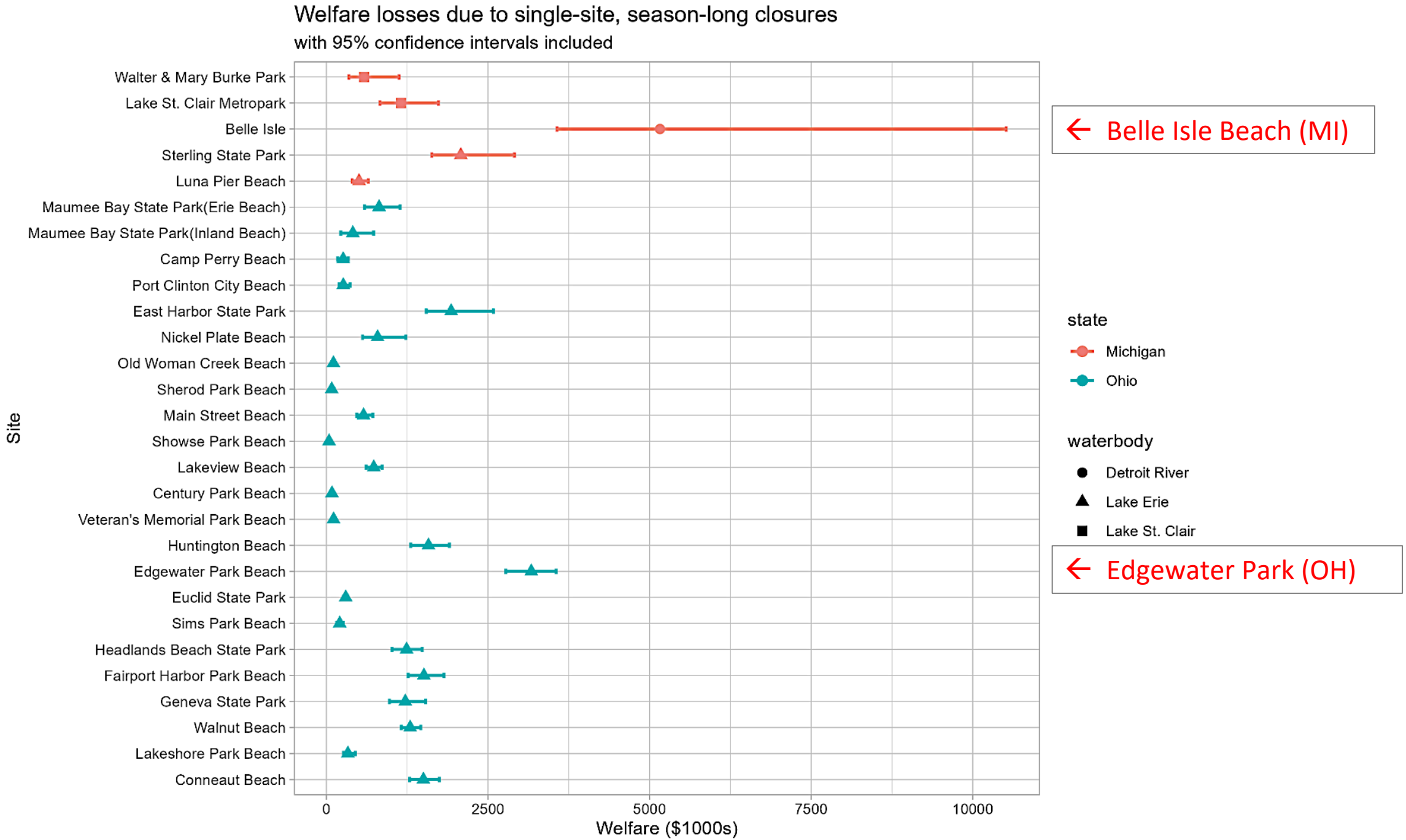
$$U_{zj} = V_{zj} + \varepsilon_{zj} = \beta_{TC} TC_{zj} + \alpha_j + \varepsilon_{zj}$$

- No-trip Utility = f(Demographics$_Z$, ε_{z0})

$$U_{z0} = V_{z0} + \varepsilon_{z0}$$

Nested logit structure




Welfare losses due to single-site, season-long closures
with 95% confidence intervals included
Walter & Mary Burke Park
Lake St. Clair Metropark
Belle Isle
Sterling State Park
Luna Pier Beach
Maumee Bay State Park(Erie Beach)
Maumee Bay State Park(Inland Beach)
Camp Perry Beach
Port Clinton City Beach
East Harbor State Park
Nickel Plate Beach
Old Woman Creek Beach
Sherod Park Beach
Main Street Beach
Showse Park Beach
Lakeview Beach
Century Park Beach
Veteran's Memorial Park Beach
Huntington Beach
Edgewater Park Beach
Euclid State Park
Sims Park Beach
Headlands Beach State Park
Fairport Harbor Park Beach
Geneva State Park
Walnut Beach
Lakeshore Park Beach
Conneaut Beach
Site
0
2500
5000
7500
10000
Welfare ($1000s)
← Belle Isle Beach (MI)
state
Michigan
Ohio
waterbody
Detroit River
Lake Erie
Lake St. Clair
← Edgewater Park (OH)

Economic impact of 2019's warnings on visitors & economic activity

- Impact on economic value ***to visitors***
  - Total seasonal losses to beachgoers in 2019: **$8.1** million
  - 26% attributable to HABs; 74% to bacteria

* All results apply only to June thru August season

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  - Lost economic contribution of **$22.2** million

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- Impact on economic value ***to visitors***
  - Total seasonal losses to beachgoers in 2019: **$8.1** million
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  - Present value losses to beachgoers $405 million

- Impact on ***local economies***
  - Lost economic contribution of **$22.2** million

- ***Present value*** losses to beachgoers & local businesses is $1.5 billion

* All results apply only to June thru August season

Results summary

- Significant aversion to sites with HAB or Bacterial warning
- Aversion persists, but declines with time since warning lifted
- Ignoring stigma effect can understate losses by 40%
- HABs in news more but damages from bacteria larger

& thanks t

Clarifying Notes

HAB warnings are not causing damages!

HAB warnings allow beachgoers to adapt and reduce damages

- Don’t go at all
- Go to a different beach
- Go to beach with warning, but avoid water…

But there may be health effects for those that do still go – our numbers have not quantified that.

& thanks t

thanks


NSF


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE