U.S. Anglers' WTP for nutrient reduction and water quality: A spatially integrated economic-ecological model of Lake Erie

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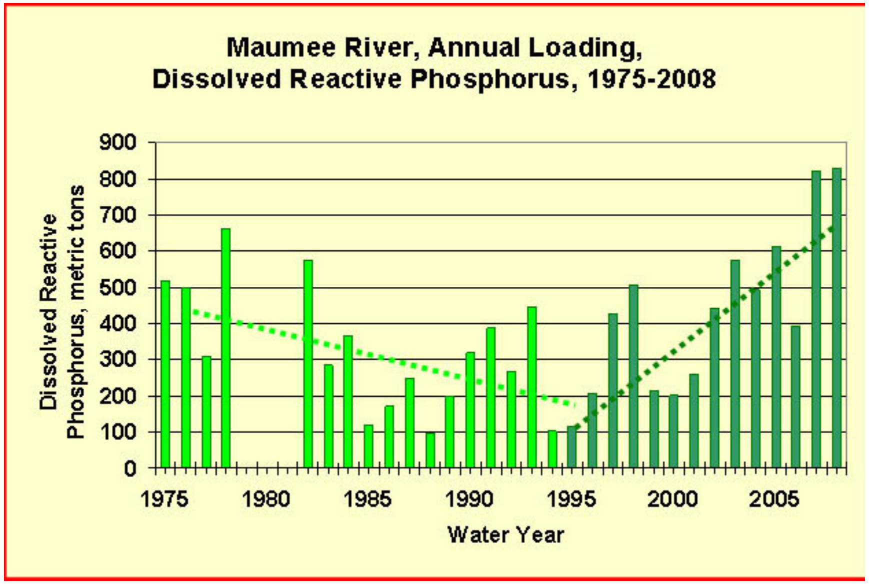
Phosphorus & Harmful Algal Blooms



Baker, D. 2009. Presentation at Great Lakes Phosphorous Forum.

Question: How do harmful algal blooms affect trip decisions and economic values.

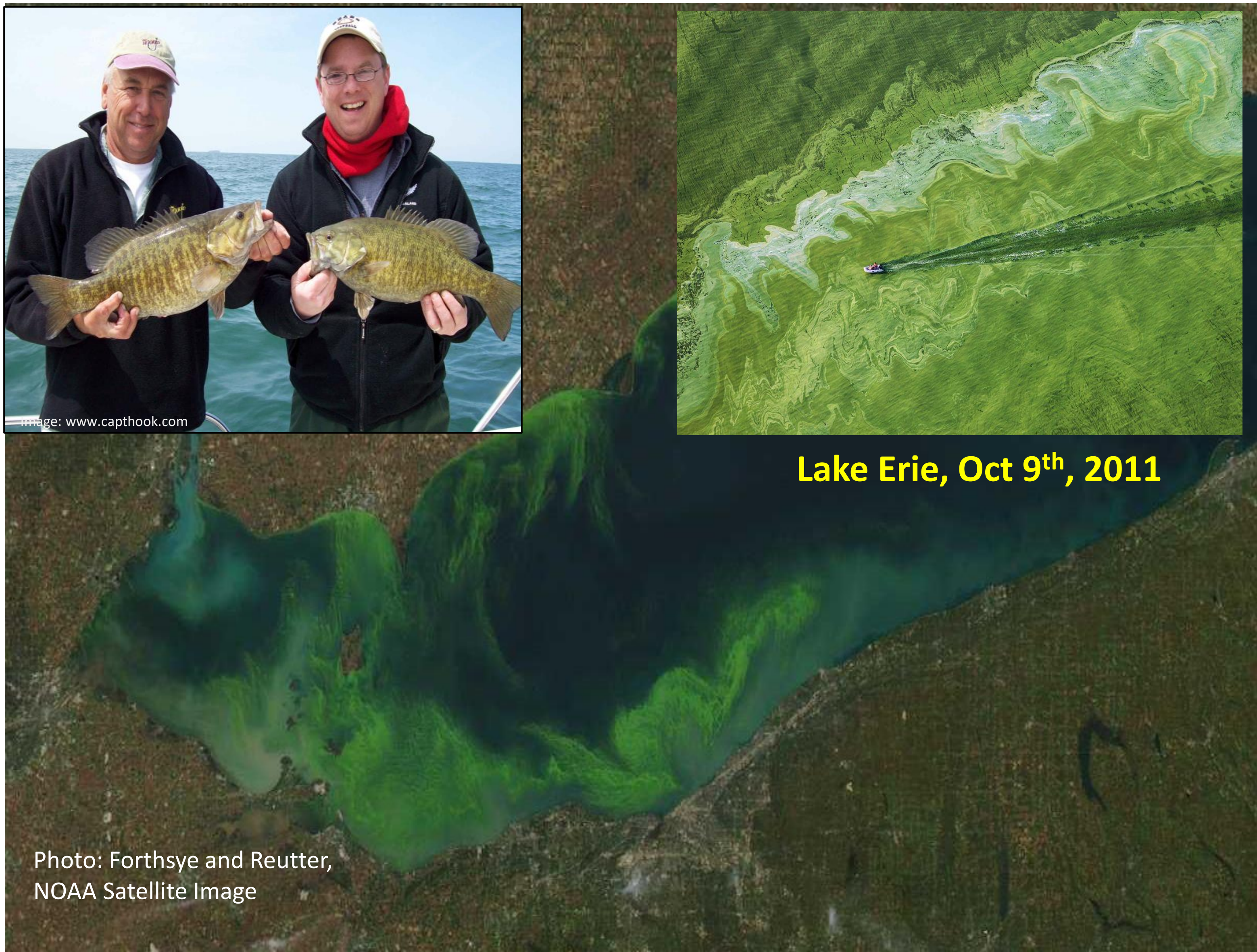


Image: www.capthook.com

Lake Erie, Oct 9th, 2011

Photo: Forthsye and Reutter,
NOAA Satellite Image

Pathways for water quality to affect utility

1. Recreation
   - Swimming, boating, fishing, etc.
2. Local amenity
   - Housing values
3. Drinking water/household use
4. Input into production of private goods
   - Commercial fisheries
5. Existence value or non-use value
   - Not related to any direct use of the environment

Related Literature

- Recreational Fishing
  - Melstrom and Lupi (2013), Kelch et al. (2006), Zhang and Sohngen (2016)
- Agricultural production and water quality
  - Diaz and Rosenberg (2008), Michalak et al. (2013)
- Combining RP and SP
  - Whitehead et al. (2010), von Haefen and Phaneuf (2008)

However, only few studies investigate HABs as economic damages to recreational fishing in the United States.

Research Questions

How does HABs affect Ohio anglers' fishing choices and its welfare implications?

The objective of this study is

- assess Lake Erie recreational anglers' WTP for water quality improvements.
- explicitly link the recent occurrences of HABs with changes in water quality characteristics. - NOAA 10-day Satellite Image
- use a combined stated and revealed preference approach.
  - Two data sources are viewed as complementary,
  - RP data provide values grounded in individual behavior, while SP data expand on the range of variation.

Lake Erie
Angler Survey

- Mailed to 3,000 randomly selected anglers based on Ohio Department of Nat. Res. fishing license database
    - 2500 to counties adjacent to Lake Erie, and 500 to other Ohio counties
    - January 2014 – April 2014
    - 2 rounds with reminder card
- Tailored Design Method (Dillman 2007)
- Pilot tested with anglers
- Response rate ≈ 25% (780 responses)
- Incentives: $1; lottery of giftcards to HomeDepot

SP Data - Choice experiments

- Prompt respondents to "*consider two alternative walleye fishing trips, which varies in several characteristics from walleye catch rate to distance from your house, and choose the trip that would appeal to you the most*"

- Collect information on fishing preference and experience, anglers' demographic and socio-economic characteristics and then present **six scenarios** for each respondent with each looking like:

One example hypothetical choice scenario

Scenario 3 :

In the following scenario, two potential sites for walleye fishing are presented. Please review the attribute levels for each site, and decide which site you would prefer. Check the box below the particular site for the one you would choose. You can choose neither by checking the box "Neither".

Attribute	Site A	Site B	Neither
Walleye catch rate at fishing site (# hours needed per fish caught per person)	6 hours	2 hours	
Miles of an algal bloom that you have to boat through before getting to the fishing site (0, 4, 8)	4	0	
Poor water clarity caused by sediments at fishing site (Very murky, somewhat murky, clear)	Somewhat Murky	Very Murky	
Time in boat getting to fishing site (minutes) 15,30,45	45	30	
Distance from house to boat ramp (miles) 20,40,60	20	60	
Which Site do you MOST prefer (Please check the box for your preferred option)	**Site A** ☐	**Site B** ☐	**NEITHER** ☐

Survey data - RP Choice questions

FISHING SITE CHOICES FOR JANUARY TO MARCH 2013

Writing directly on the map below, **state the number of day trips for fishing you took to each grid** during the period **January – March, 2013**. Please mark your number of trips for the specific grid to which you took the trips. Since some trips may have included time spent in two or more grids, please attribute the entire trip to the grid in which you spent the most time. Please write your answers as clearly as possible. If you did not take a trip to any particular grid, please leave it blank. Please also **circle the boat ramps** (denoted as triangle in the maps) from where you mainly used to launch the boat this winter.

Please also circle the approximate location of the boat ramps (denoted as triangle in the maps) you most often used

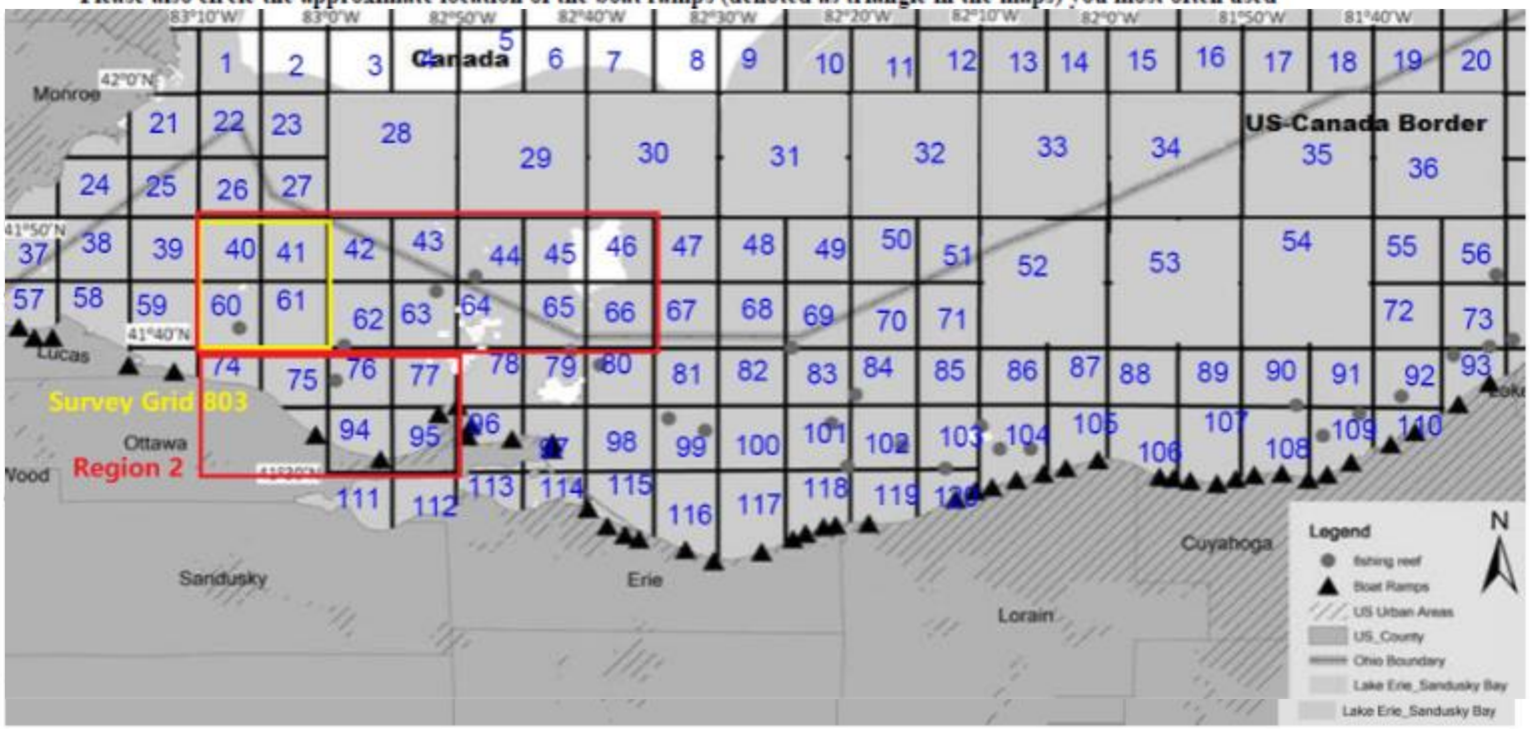


Figure: Example: RP Choice Question

RP – Estimation Choice Set

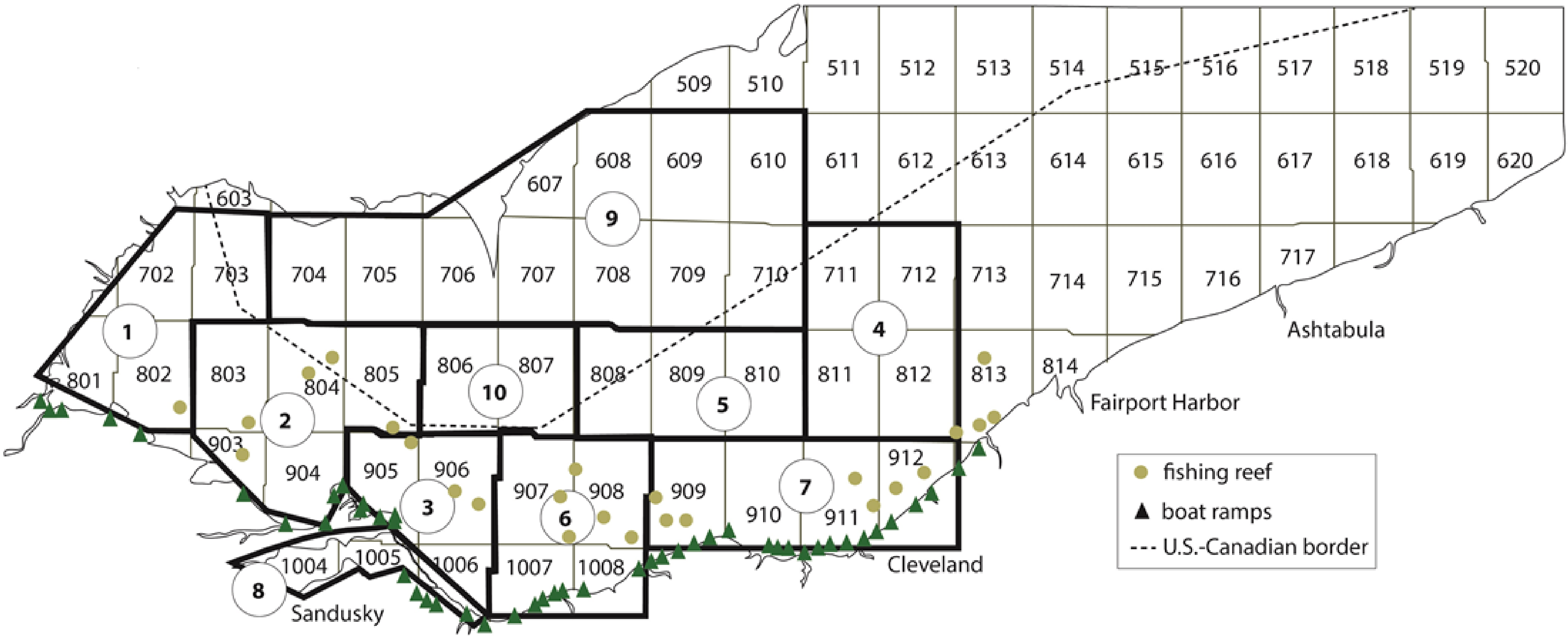


Figure 2. Survey fishing site grids (marked with blue numbers), Ohio DNR creel survey grids (marked in yellow), and 10 fishing site regions used in the RP estimation (marked in red)

Harmful Algal Bloom

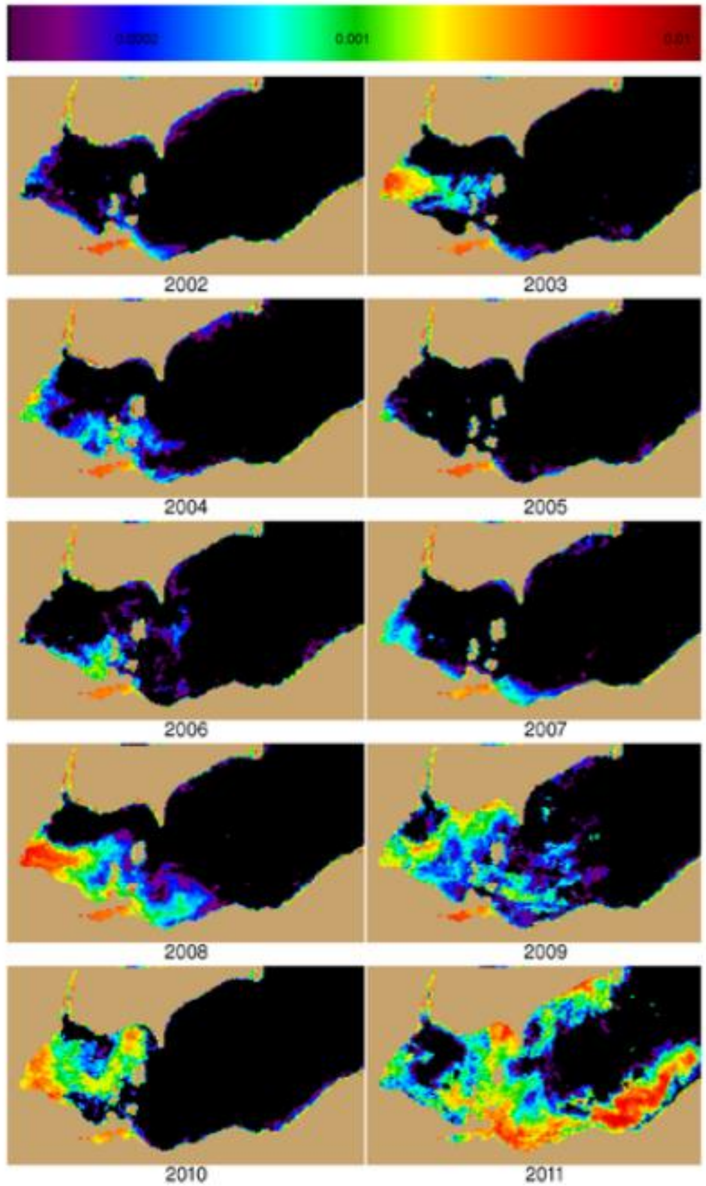
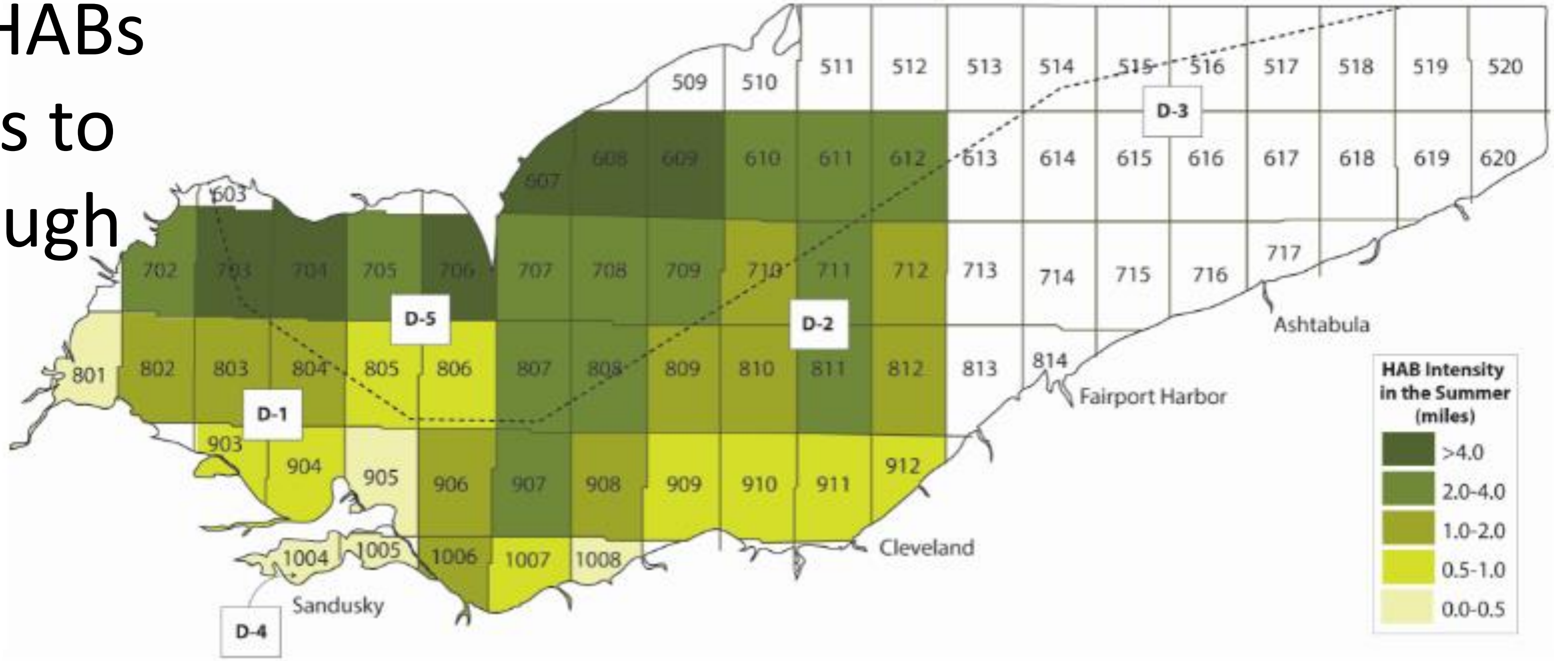
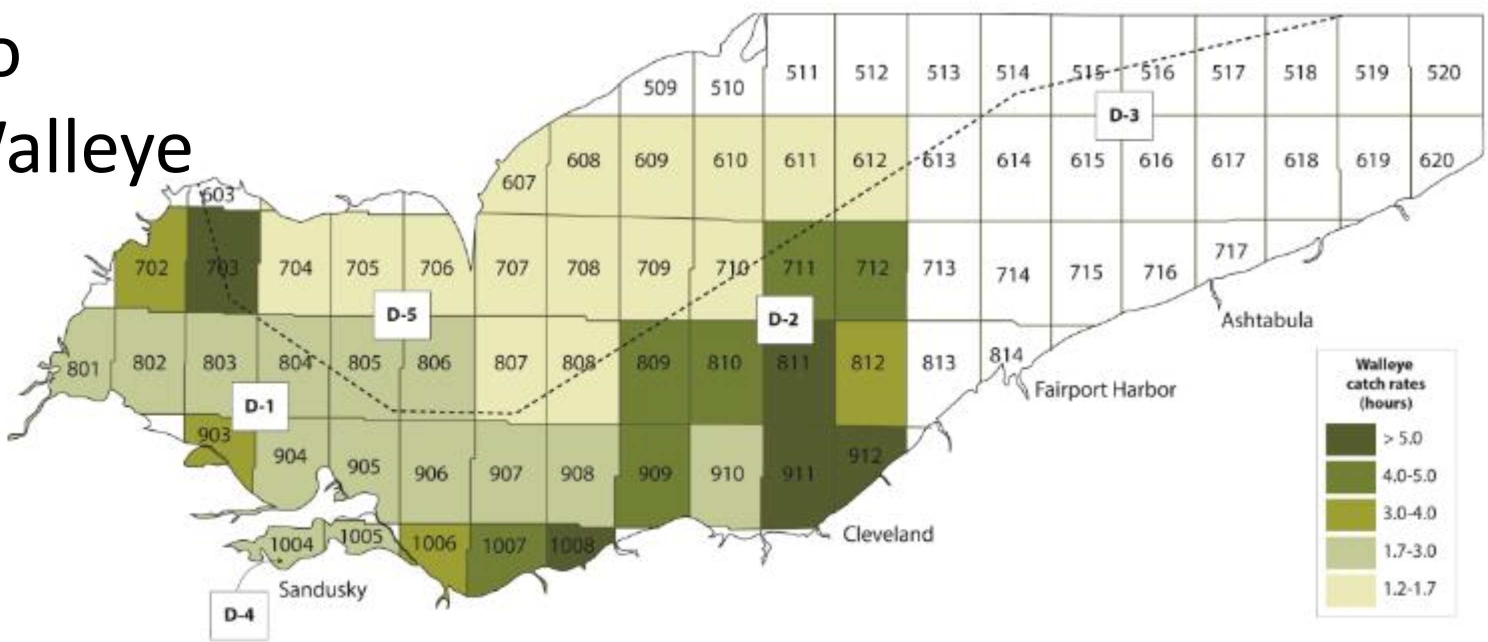


Figure: 10 Day HAB Data (satellite image) from NOAA

Miles of HABs angler has to boat through



Hours Needed to Catch a Walleye



Summary Statistics

Variable	Description	Mean	S.D.	Min	Max
Travel Cost	Travel cost from home to nearest boat ramp ($)	**96.73**	120.53	1.96	1884.33
dist_boat	Boating distance from boat ramp to fishing site (miles)	**15.95**	1.03	2.86	37.01
hab_dist	Miles of algal bloom to boat through	**2.14**	0.71	0.21	8.00
clarity_clear	Dummy for very clear water	**0.11**	0.27	0	1
clarity_med	Dummy for somewhat murky water	**0.77**	0.42	0	1
walleye	Number of hours to catch one walleye	**1.22**	11.83	3.86	1.30
neither	Dummy for choosing "neither"	**0.33**	0.47	0	1
own boat	Dummy for owning a boat	**0.73**	0.40	0	1
blooms	Dummy of having experienced HABs in previous fishing trips	**0.86**	0.35	0	1
Hab_changeloc	Dummy of having changed fishing locations if experienced HABs	**0.55**	0.50	0	1

Empirical Strategy: Combine RP and SP

Following von Haefen and Phaneuf (2008),

$$\begin{aligned} U_{ijt}^{RP} &= X_j^{RP}\beta_i + \xi_j + Z_i \cdot X_{ij}^{RP}\gamma + \tau_i P_{ij}^{RP} + \mu^{RP}\varepsilon_{ijt} \\ U_{ikh}^{SP} &= X_{ikh}^{SP}\beta_i + \qquad Z_i \cdot X_{ikh}^{SP}\gamma + \tau_i P_{ikh}^{SP} + \mu^{SP}\varepsilon_{ikh} \end{aligned}$$

- j 1,... 10 regions based on fishing grids
- X_j^{RP}, X_j^{SP}: observed site attributes
- Z_i: individual characteristics
- $P_{ij}^{RP}, P_{ikh}^{SP}$ travel costs
- $\varepsilon_{ijt}, \varepsilon_{ikh}$: *iid* Type I extreme value error
- μ^{RP}, μ^{SP}: scale factor
- ξ_j: Alternative Specific Constants (ASC's)

Results – grid RP choice + choice experiment

	SP		RP		Combined RP/SP	
Variable	MNL	MXL	MNL	MXL	MNL	MXL
Scale	-	-	-	-	**0.065**	**0.114**
	-	-	-	-	(9.47)	(17.9)
Travel Cost	**-0.002**	**-0.006**	**-0.042**	**-0.050**	**-0.041**	**-0.048**
	(-5.70)	(-9.14)	(-12.4)	(-11.2)	(-31.4)	(-27.7)
dist_boat	-0.003	0.001	**-0.129**	**-0.187**	**-0.114**	**-0.150**
	(-1.65)	(0.28)	(-15.4)	(-12.1)	(-20.7)	(-21.5)
hab_dist	**-0.060**	**-0.106**	0.037	**-0.184**	**-0.089**	**-0.449**
	(-9.08)	(-10.0)	(0.72)	(-2.02)	(-2.58)	(-9.83)
clarity_clear	**0.643**	**0.912**	0.265	**-2.867**	**0.596**	**2.153**
	(12.2)	(10.3)	(0.88)	(-5.09)	(4.40)	(10.9)
clarity_med	**0.443**	**0.598**	**0.487**	**3.234**	**0.453**	**2.475**
	(8.42)	(8.27)	(3.47)	(7.64)	(6.27)	
Walleye	**-0.322**	**-0.620**	**-0.287**	**-1.190**	**-0.357**	**-1.728**
	(-25.5)	(-16.4)	(-6.63)	(-9.92)	(-16.0)	(-1.59)
Neither	**-1.551**	**0.520**	-	-	**-16.072**	**-3.375**
	(-16.9)	(14.7)	-	-	(-20.0)	(-12.4)
Standard Deviation						

Average Marginal WTP by anglers for water quality interpretation :

1. $36 for one less hour of catching one walleye
2. $9.4 for one less mile of HAB to travel through before reaching preferred fishing site
3. $45 for water quality changing from murkier water to clear

Results – with regional ASCs and interactions

Table 3. Mixed logit models (MXL) with interactions or regional ASCs

	SP	RP	Combined RP/SP		
	with Interactions	with Interactions	with Interactions	with ASCs	with Interactions and ASCs
Scale	-	-	**0.112**	**0.088**	**0.083**
	-	-	(17.9)	(17.2)	(16.8)
Travel Cost	**-0.006**	**-0.050**	**-0.047**	**-0.069**	**-0.071**
	(-9.30)	(-11.3)	(-28.7)	(-28.1)	(-26.7)
hab_dist	**-0.098**	**-0.669**	**-0.773**	**-0.868**	**-1.208**
	(-5.26)	(-2.78)	(-7.77)	(-12.5)	(-8.17)
own_Boat	-0.010	0.262	**0.183**	-	0.194
	(-0.46)	(1.87)	(2.23)	-	(1.70)
blooms	0.007	0.119	**0.287**	-	0.126
	(0.27)	(0.51)	(2.49)	-	(0.77)
hab_changeloc	-0.018	**0.287**	-0.025	-	**0.269**
	(-0.75)	(2.02)	(-0.28)	-	(2.20)
walleye	**-0.605**	**-0.627**	**-2.184**	**-2.679**	**-3.106**
	(-10.5)	(-3.82)	(-14.1)	(-19.9)	(-16.1)
own_Boat	-0.110	-0.199	**-0.304**	-	**-0.773**
	(-1.75)	(-1.20)	(-2.80)	-	(-6.16)
blooms	-0.103	-0.377	**0.616**	-	**1.306**
	(-1.31)	(-1.87)	(3.61)	-	(6.51)
hab_changeloc	**0.276**	-0.112	0.205	-	**-0.289**
	(3.83)	(-0.66)	(1.64)	-	(-2.40)

Policy Scenarios

Table 4. Nutrient reduction and site closure policy scenarios

Panel A: Nutrient Reduction Policy Scenarios					
	Policy scenario	Variable values			
Policy	Description	*walleye*	*hab_size*	*clarity_clear*	*clarity_medium*
	baseline	1.2	3	0	1
NR1	10% reduction in Maumee DRP loading	1.2	3	0.2	0.8
NR2	20% reduction in Maumee DRP loading	1.2	2.5	0.3	0.7
NR3	40% reduction in Maumee DRP loading	1.2	1	0.7	0.3
Panel B: Site Closure Scenarios					
Policy	Closure Grids	Closure Description			
SC1	1004, 1005	Sandusky Bay			
SC2	805, 806, 905, 906	Grids around major Lake Erie islands			
SC3	803, 804, 903, 904	Most popular near-shore fishing destinations			

Welfare Estimates – Nutrient Reduction Scenarios

Table 5. Welfare gain estimates from nutrient reduction scenarios ($/trip)

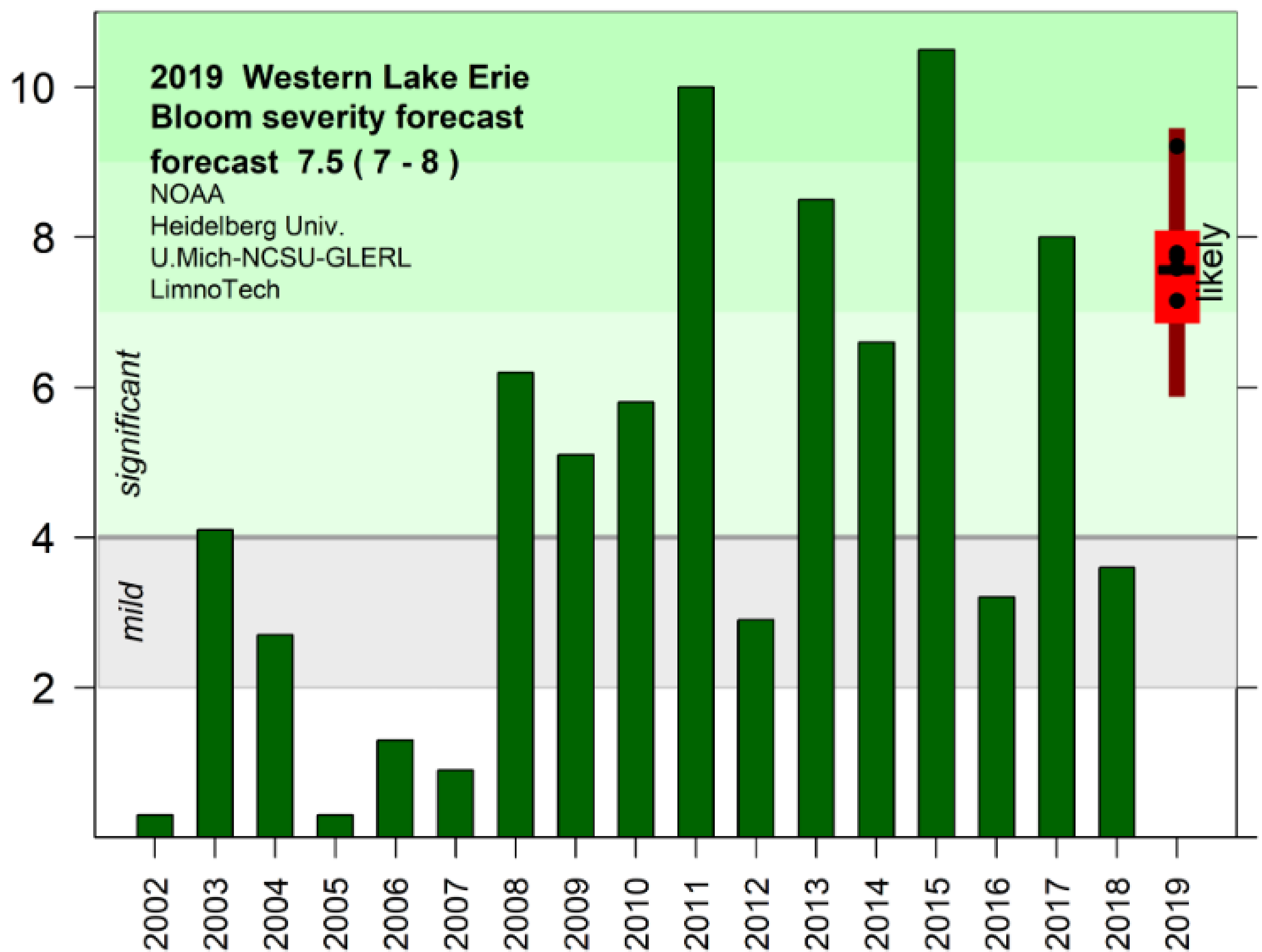
Nutrient Reduction Scenario	SP Only	RP data with SP coefficients		
	MXL with Interactions	MNL with Interactions	MXL with Interactions	MXL with Interactions and ASCs
10% less spring P loadings	**$10.34**	**$20.20**	**$7.98**	**$8.33**
from Maumee	(2.65)	(6.60)	(2.55)	(2.32)
20% less spring P loadings	**$24.66**	**$45.81**	**$19.31**	**$19.60**
from Maumee	(4.49)	(11.75)	(4.16)	(3.83)
40% less spring P loadings	**$71.91**	**$132.75**	**$57.30**	**$57.59**
from Maumee	(11.66)	(31.21)	(10.58)	(9.78)

Welfare Estimates – Fishing Site Closure Scenarios

Table 6. Welfare loss estimates from fishing site closure scenarios ($/trip)

Fishing Site Closure Scenario	RP	Combined RP/SP		
	with Interactions	with Interactions	with ASCs	with Interactions and ASCs
Sandusky Bay	**-$5.26**	**-$5.43**	**-$3.69**	**-$3.11**
	(0.70)	(0.31)	(0.35)	(0.29)
Put-in-Bay Islands	**-$3.32**	**-$4.96**	**-$4.69**	**-$5.68**
	(0.48)	(0.29)	(0.57)	(0.58)
Popular Nearshore Grids	**-$5.50**	**-$6.14**	**-$4.38**	**-$4.86**
	(0.50)	(0.26)	(0.25)	(0.24)

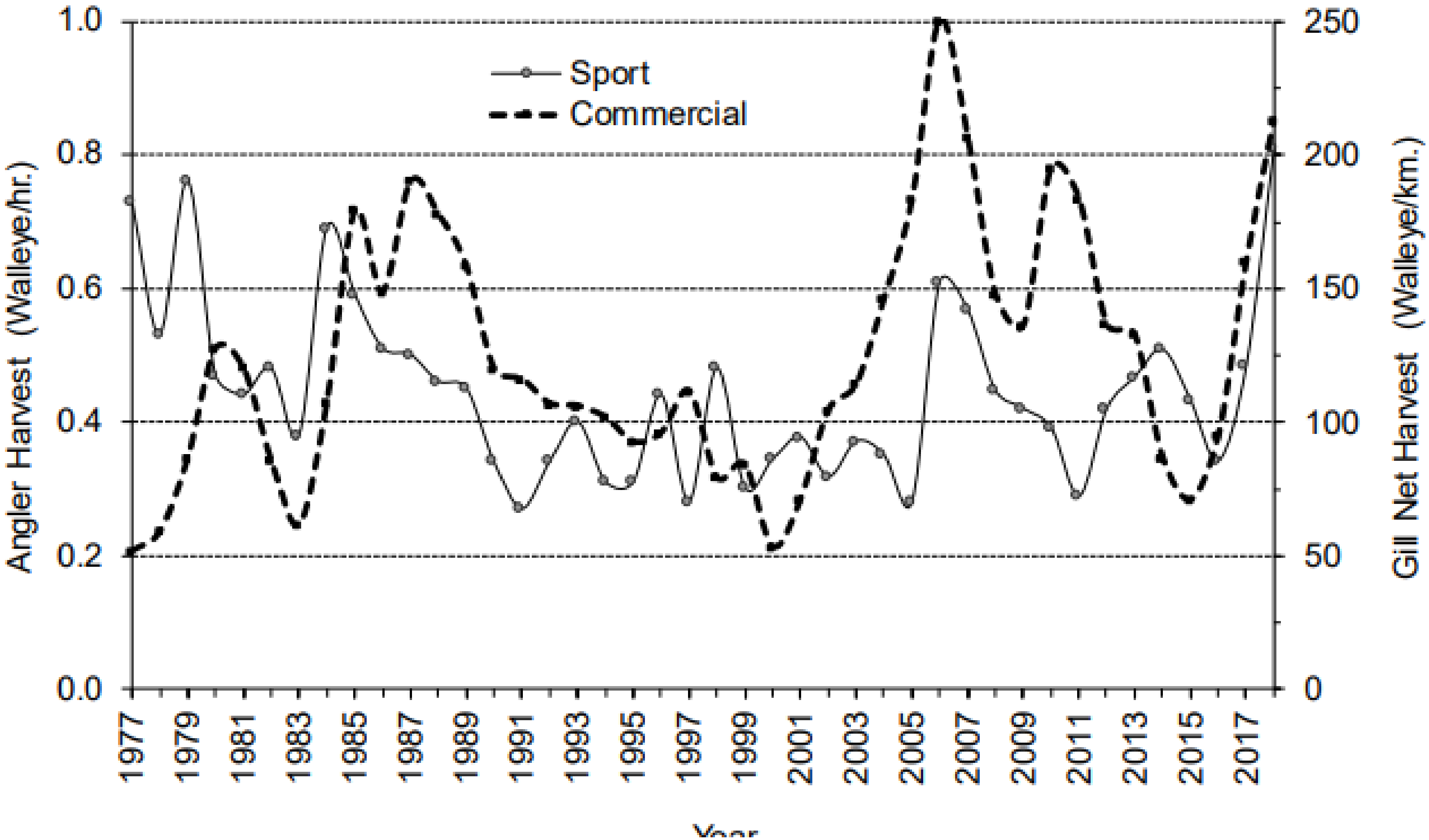
Grid-explicit scenarios to link with 3-D hydrodynamic-ecological model (ELCOM-CAEDYM)



Grid-explicit scenarios to link with 3-D hydrodynamic-ecological model (ELCOM-CAEDYM)

high T, high P: 2011; low T, high P: 2015

low P, high T: 2012; low P low T: 2006



Conclusion and Future Work

- Our combined RP/SP approach might be a better way to give reasonable & trustworthy estimates of ecological services than the standalone RP or SP models.
  - Allow for linkage with spatially-explicit ecological model to capture realistic spatially-explicit water quality impacts to policy scenarios
- Our results also reveal the potential for linking widely available satellite imagery into credible measures of water quality amenities in non-market valuation studies

Thank You!

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3D whole lake linked hydrodynamic – biogeochemical model (ELCOM-CAEDYM)