At Blackwater Pond

At Blackwater Pond the tossed waters have settled

After a night of rain.

I dip my cupped hands. I drink

A long time. It tastes

Like stone, leaves, fire. It falls cold

Into my body, waking the bones. I hear them deep inside me, whispering

Oh what is that beautiful thing

that just happened?

--- Mary Oliver

The Social Cost of Water Pollution: Theory and Implications

Presented by

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LEEP

June, 2019

(with Dave Keiser and Dan Phaneuf)

Funding from the Atkinson Center at Cornell, USDA, EPA, the Iowa DNR, and the National Science Foundation much appreciated.

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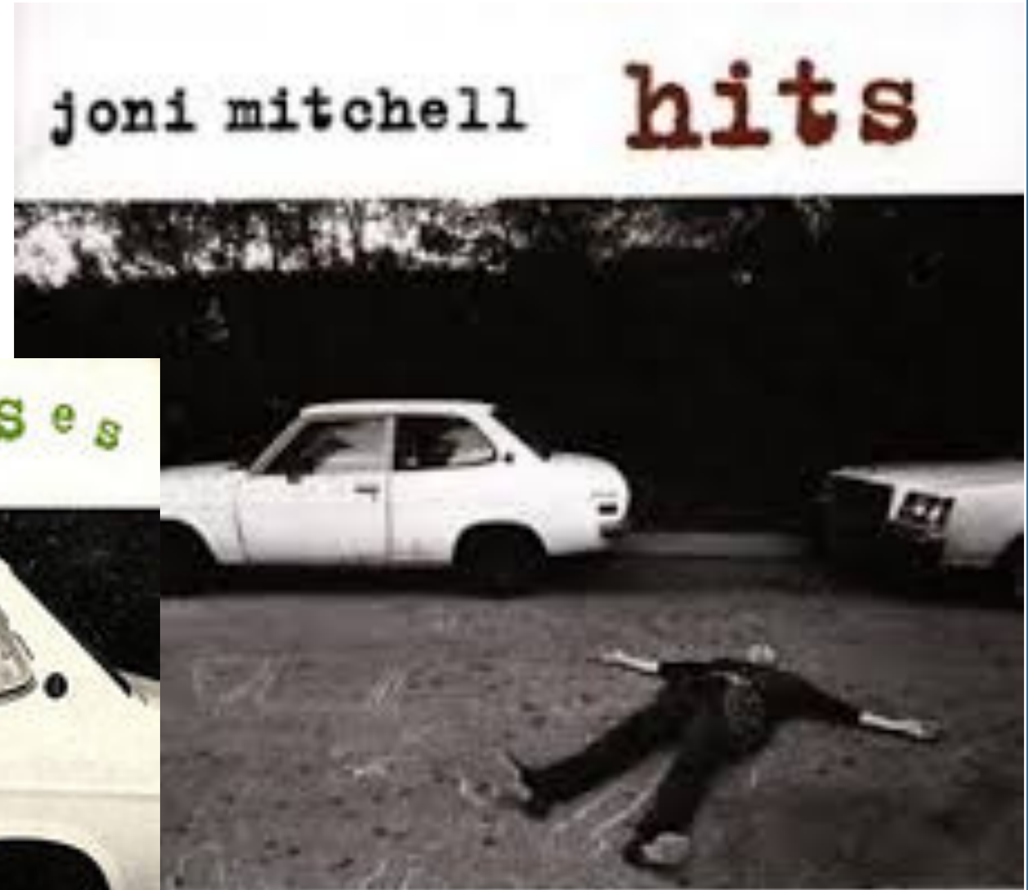
Greatest Hits?



The Social Cost of Water Pollution: Lake Erie

National Geographic, Lake Erie

- Drinking water, costs to public drinking supplies
- Water contact, health risks

Toxin leaves 500,000 in northwest Ohio without drinking water”

REUTERS August 2, 2014

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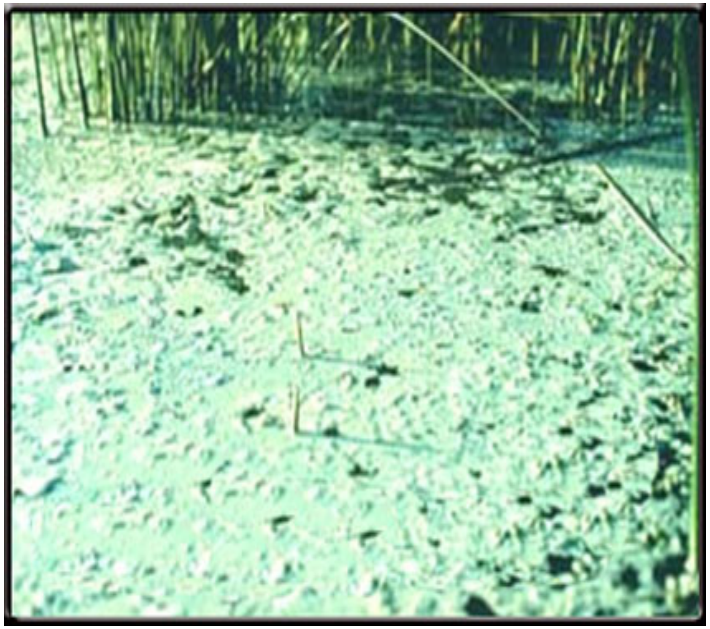
The Social Cost of Water Pollution: Local Lakes and Streams

- Recreation
- Wildlife Habitat
- Rural Drinking water – unregulated wells
- Nonuse value?



A cyanobacteria bloom in a Midwestern lake.

Ducks swimming in eutrophied waters: Source: National Geographic

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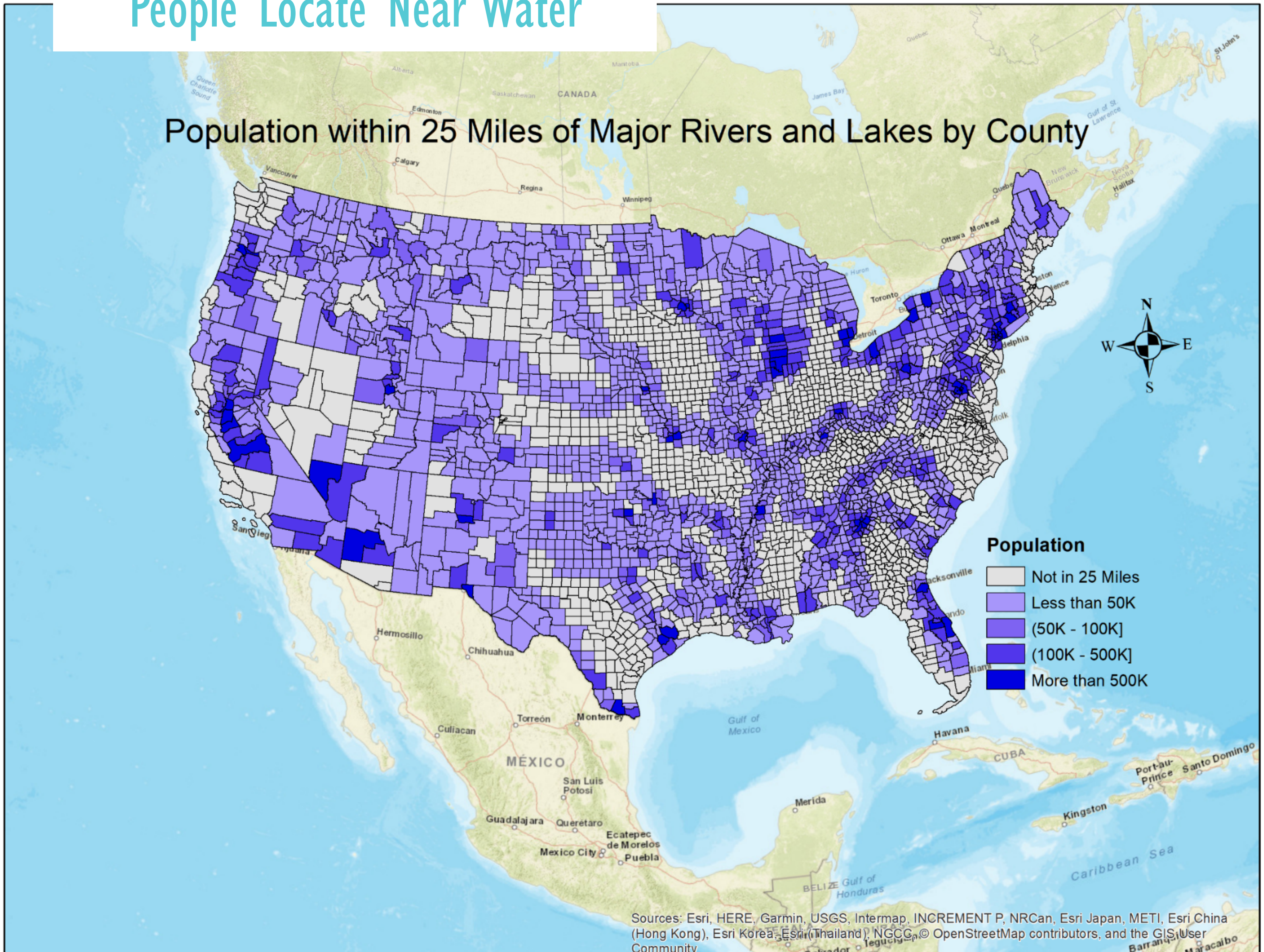
People Locate Near Water



142 million (~50%) live within 25 miles of major rivers

Over 200 million if include coasts

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Social Cost of Water Pollution: Standing on the Shoulders of Rock Stars

Social Costs of Nitrogen (Polasky and friends)

- Tracked N fertilizer movement in Minnesota and damages

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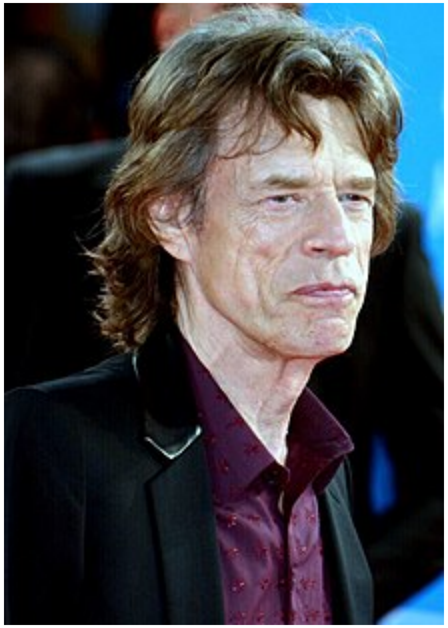
Social Cost of Water Pollution: Standing on the Shoulders of Rock Stars

The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water (Carson and Mitchell)



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Social Cost of Water Pollution: Standing on the Shoulders of Rock Stars

Deepwater Horizon!

Roger von Haefen aka Yes lead man

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Social Cost of Water Pollution: Standing on the Shoulders of Rock Stars

Sir Bateman at 18

Bringing Ecosystem Services into Economic Decision-making: Land use in the UK (Bateman, Binner, Day, Fezzi, and friends)

- Science paper: Tour de force of landscape-scale valuation with multiple ecosystem services
- NEVO
- ORVal

Those who actually do the work

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Social Cost of Water Pollution: Why does it matter?

1. BCA can drive policy decisions
   US Federal Policy requirements

2. What do we know about the benefits and costs of major water quality regulations in the U.S.?

Benefit-Cost Ratios

Table 1. CBAs of water quality programs

Regulation	Study time frame	Benefit-to-cost ratio
CWA		
Freeman (6)	1985	0.19–1.23
Carson and Mitchell (7)	1990s	0.61–1.25
Lyon and Farrow (8)	1990s	0.25–1.16
US EPA (21, 61)	1990s	0.79–0.88
Keiser and Shapiro (1)	1962–2001	0.24
WOTUS		
Obama Administration	2015	1.10–2.41
Trump Administration	2017	0.11–0.30
CRP		
Hansen (47)	2000s	0.76–0.87
Effluent Guidelines		
Centralized Waste Treatment	2000	0.07–0.23
Landfills	2000	0.00
Transportation Equipment Cleaning	2000	0.11–0.33
Waste Combustors	2000	0.15–0.5
Coal Mining	2002	>1
Iron and Steel Manufacturing	2002	0.11–0.58
Concentrated Animal Feeding Operations	2003	0.61–1.06
Metal Products and Machinery	2003	0.09
Concentrated Aquatic Animal Production	2004	0.05
Meat and Poultry Products	2004	0.05
Construction and Development	2009	0.39
Steam Electric	2015	0.94–1.1[illegible]

Average B/C ratio ~0.5
Median ~0.4

David A. Keiser et al. PNAS doi:10.1073/pnas.1802870115

Why?

1. Costs exceed benefits due to:

    - Poor program design (not cost effective)?
    - Low benefits – water quality low value?

2. Measurement issues :

    - Costs over stated?
    - Benefits understated?
        - Missing measures of ecosystem service effects
        - Missing valuation of those endpoints
        - Benefits omitted

Water Pollution Damages

EPA is Aware of Missing Pieces problem

McGartland et al. Science, Policy Forum 2017

“When EPA judges evidence to be “suggestive” or—as is typical for noncancer health effects—there is no summary descriptor from an authoritative review of the evidence, EPA generally excludes the potential health risk from its primary quantitative benefits analysis …This practice implicitly assumes that exposed populations have zero WTP for reduced exposure when there is some evidence of an adverse health effect but that evidence is not unambiguous. This assumption violates economic principles and is contradicted by findings.”

US Presidential Executive Orders Requiring Cost Benefit/ Regulatory Impact Analysis

Year	Legal Mandate	Decision Rule
1981, Reagan	Executive Order 12291	Regulatory action shall not be undertaken unless the potential benefits to society from the regulation outweigh the potential costs to society; Regulatory objectives shall be chosen to maximize the net benefits to society;
1993, Clinton	Executive Order 12866	… in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires another regulatory approach.
2011, Obama	Executive Order 13563	…each agency must… propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify) select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other adgantages; distributive impacts; and equity) Regulations shall be adopted through a process that involves public participation.

US Presidential Executive Orders Requiring Cost Benefit/ Regulatory Impact Analysis

Year	Legal Mandate	Decision Rule
2017 Trump	Executive Order 13771	… for every one new regulation issued, at least two prior regulations be identified for elimination …the total incremental cost of all new regulations, including repealed regulations, to be finalized this year shall be no greater than zero.
2017 Trump	OMB M-17-21 Guidance for Implementing EO 13771	There are several types of impacts that could be…reasonably categorized as either benefits or costs, with the only different being the sign (positive or negative) on the estimates. In most cases, where there is ambiguity in the categorizations of impacts, agencies should conform to the cost conventions they have followed in past analyses. For example, if a medical cost savings due to safety regulations have historically been categorized as benefits rather than reduced costs, they should continue to be categorized as benefits. for deregulatory actions…the medical cost savings described above as historically being counted as benefits when regulating should not then be counted as “negative cost savings” when deregulating.

By deregulating, the costs of medical care will increase, but this will not be counted as a cost of deregulating

Social Cost of Water Pollution

Degraded water quality impacts welfare through multiple channels:

Drinking water

Recreation

Amenity Value

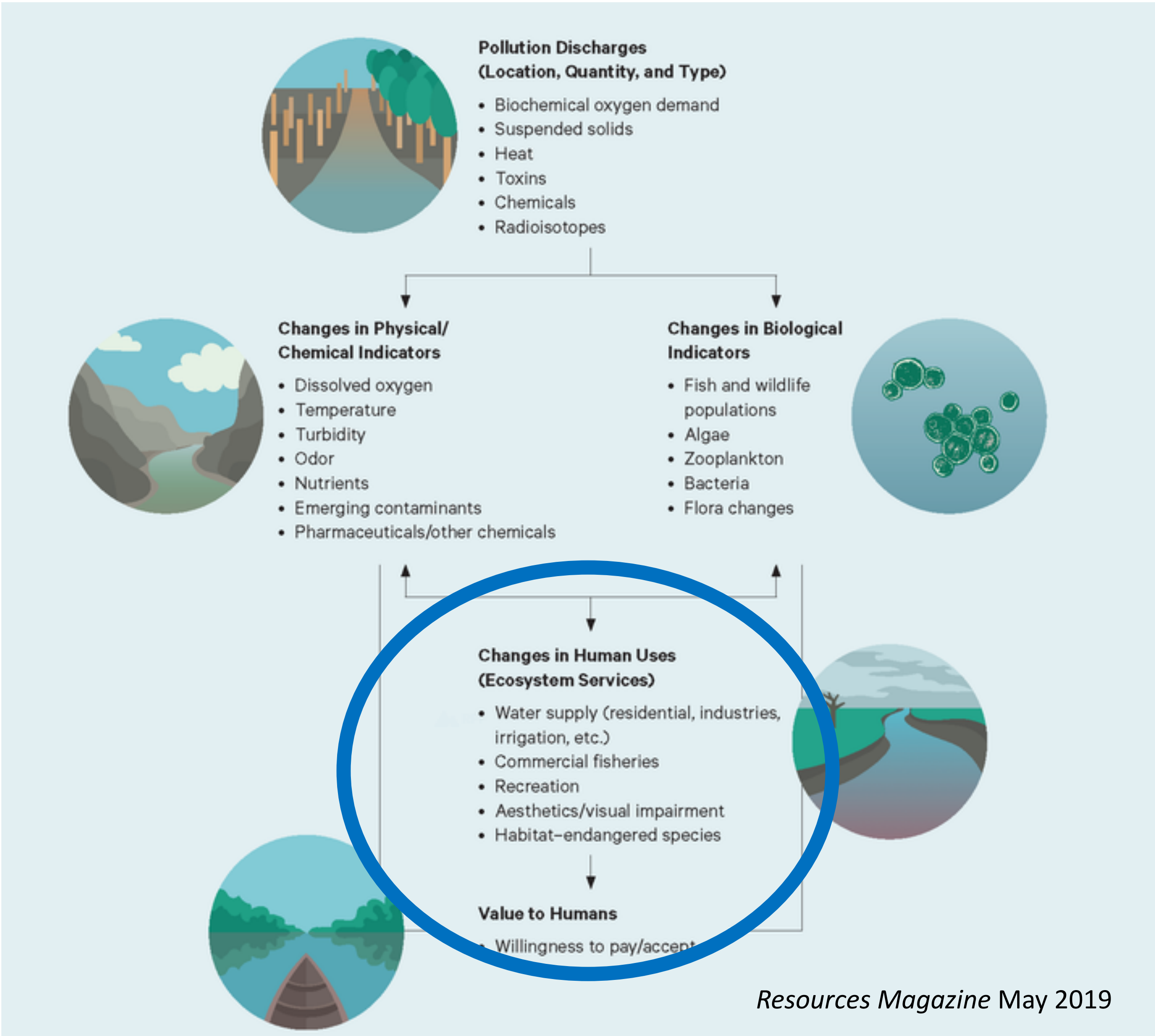
Existence

How do we more completely capture the costs of water pollution?

Integrated Assessment Model

- Link spatially explicit hydrology with
- Value generating mechanisms and
- Valuation endpoints

Schematic: Integrated Assessment Model



Resources Magazine May 2019

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Using an IAM to Develop the Social Costs of Water Pollution

Questions

1. What are the mechanisms through which changes in water quality can affect well-being?
2. What empirical valuation methods can recover the components of values?
3. Are valuation measures from these mechanisms additive?
4. What structural assumptions are useful/needed when jointly considering multiple mechanisms?
5. Can we test these assumptions?

Draw on theory and empirical methods to answer

Model: Mechanisms

- Recreation visits
- Amenity value, water quality and distance to lakes
- Drinking water, health effects
- Existence (nonuse) value

$$U_n = U_n\left(x, d, F, h\left(f\right), z, q\right)$$ n = 1,…,N neighborhoods,

x= vector recreation visits
d=vector distances to waterbodies from neighborhood n
F = f+b is the total units of drinking water
$h(\cdot)$ = health production from drinking water
z= all other goods
q =vector of water qualities

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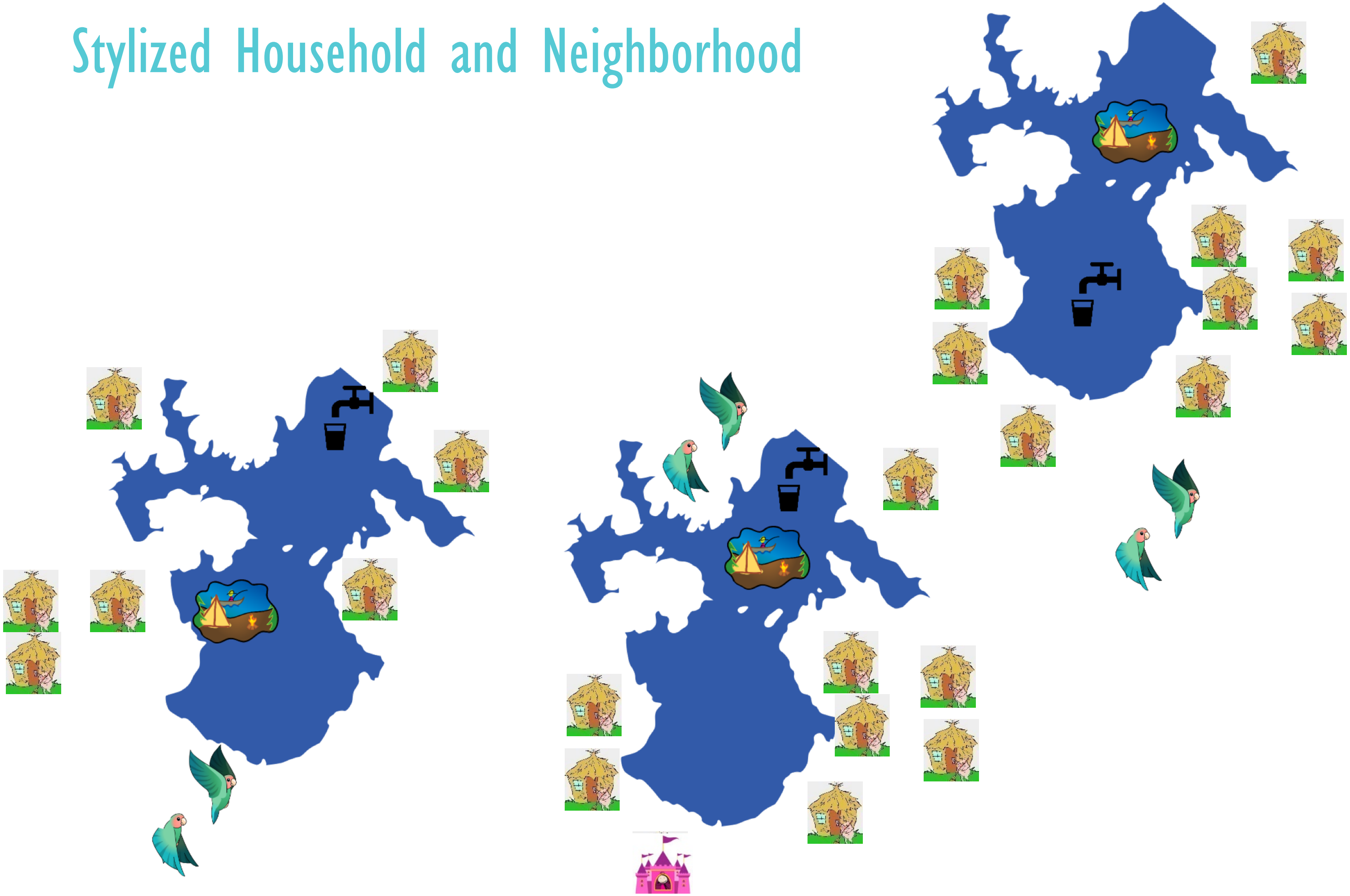
The Social Cost of Water Pollution: Stylized Household and Neighborhood



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Model: Adding Structure

$$U_n = u_n^c\left(x, d_{a(n)}, F, h\left(f\right), z, q\right) + u^e(q)$$

Additive component:

1. Additively separable piece of the utility function --- existence value
2. Include entire vector of water qualities of all lakes

Implications:

1. Hedonic house price function, recreation demand, bottled water demand will not depend on changes in q through existence value

2. All lakes, large and small have potential to generate existence values

Model: Adding Structure

Sequential decision making:

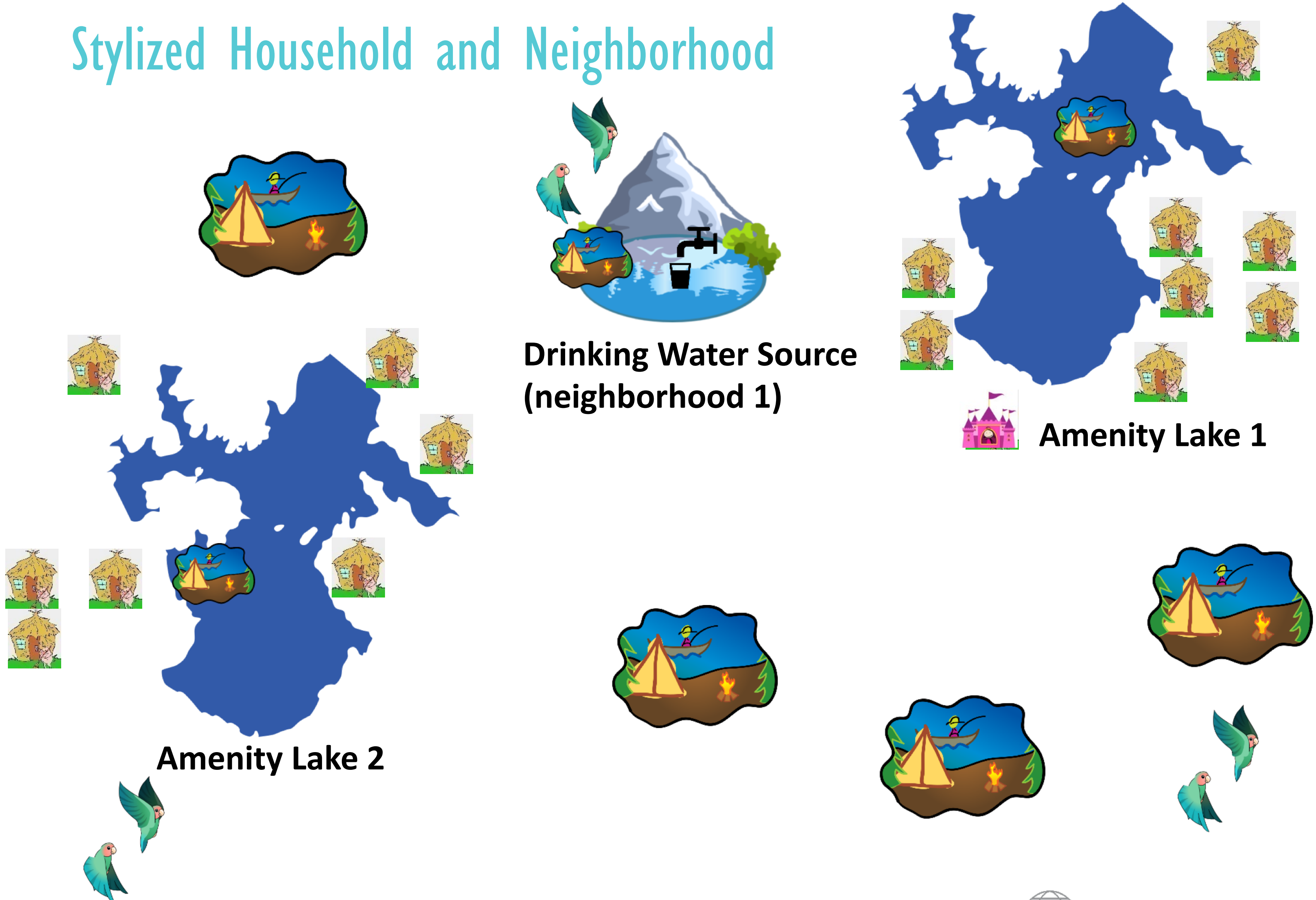
1. Household chooses house and neighborhood based on:
   - Water quality of amenity lake ($q_{a(n)}$)
   - Distance to amenity lake ($d_{a(n)}$)

2. Conditional on neighborhood choice and house, household chooses:
   - Number of visits to recreation sites (including amenity lake, j=1)
   - Amount of bottled water to purchase (drinking water lake, j=2)

Implications:

1. Distance and water quality at j=1 for amenity and recreation value will be capitalized in hedonic price function
2. Value of water quality at all other locations will NOT be capitalized
3. Drinking water quality, cost of bottled water will NOT be capitalized

The Social Cost of Water Pollution: Stylized Household and Neighborhood



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Model: Decision Problem

Stage 1: Choose $q_{a(n)}$ and $d_{a(n)}$

Stage 2: Choose x_1 , f, and b

Behavioral equations (observable footprints) :

$x = x(c, q; Y, q_{a(n)}, d_{a(n)})$ = system of recreation demand equations
$b = b(q_{d(n)}, p_b, t_n; Y, q_{a(n)}, d_{a(n)})$= demand for bottled water
$P_n = P(d_{a(n)}, q_{a(n)}; Y)$= hedonic price function

Y = annual income
t_n= fee for water treatment
p_b = price of bottled water
c = cost to access recreation sites

Note: more structure added by variable inclusion

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Discussion: model assumptions

1. Households do not choose their neighborhood based on

- water quality or distance to recreation sites other than their amenity site
- quality of drinking water or cost of treating drinking water

Why might this be reasonable?

i. these items are too small as share of budget for households to consider
ii. Households are limited in cognitive capacity to consider too many components in choosing locations
iii. all neighborhoods have similar access to equal quality recreational lakes and drinking water

How can we test these assumption?

Evidence on Capitalization

Significant capitalization of important/large disamenities

- Christiansen, Keiser, and Lade (2019): 29% impact from Flint crisis
- Wolf and Klaiber (2017): 22% decrease for a toxic algae bloom
- Davis (2004): 14 -16% decline for a cancer cluster
- Haninger et al (2017): 15% increase for brownfield remediation
  Muehlenbachs et al. (2015): 14% for shale gas well pad siting
- Currie et al. (2015): 11% decrease for the opening of a toxic plant
- Mendelsohn et al. (1992): 8% decrease for hazardous waste discovery
- Billings and Schnepel (2017): 32 % increase from lead remediation

But these are large and well publicized, can we infer from these cases that capitalization occurs for small budget items?

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Evidence on Capitalization

Evidence that capitalization is incomplete/inaccurate

- Bakkensen and Barrage (2017): coastal residents report erroneously low flood risk and conclude that "coastal prices currently exceed fundamentals by 10%. Ignoring heterogeneity leads to a four-fold underestimate of future coastal home price declines due to sea level rise."

How to test appropriateness of capitalization assumption?

Bakkensen and Barrage combine detailed household survey eliciting individual household level flood risk perceptions. Their methodology can be extended to other markets

Discussion: model assumptions

2. Households do not choose their neighborhood based on proximity to lakes that generate non use values

This is at odds with the literature that estimates the extent of the market for nonuse values

- Bateman, Day, Georgiou, Lake (2006) – distance decay and welfare measures
- Pate and Loomis (1997) – nonuse value for wetlands and salmon, limits to market size

If existence value is a function of distance, then in theory it could be capitalized in to home values...?

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Discussion: model assumptions

3. Bottled water is a perfect substitute for drinking water and has no negative health effects

Estimates for values of water quality changes that impact drinking can be recovered using defensive expenditures (averting behavior model)

Because b is assumed perfect substitute for q_2, marginal and nonmarginal values will be exact (no missing utility pieces)

How to test whether b is a perfect substitute for tap water of a given quality?

household surveys? Can bottled water sales data be used?

Discussion: other assumptions

4. Water quality measures are accurate, match consumer perceptions, and are the same for each mechanism

5. Static model, perfect certainty throughout

Marginal Social Cost of Pollution

What is the marginal social cost of a unit of emissions?

Imagine that pollution impacts all water bodies through each mechanism

Assume hydrological relationships known, i.e., $\frac{\partial q_i}{\partial e}$ known

$$V(q_1,\ldots,q_J,P_{in},\tau_n,p_b,d,c,Y)=\max_{x,d_1,b,f,z} u_{in}^c\left(x_{i1},\ldots,x_{iJ},d_{i,a(n)},F_i,h\left(f_i\right),z_i,q\right)+u_i^e(q)+$$

$$\lambda\left(Y-z-P(d_1,q_1)-t(q_2)-p_b b-d_1\cdot c\cdot x_1-\sum_{j=2}^{J} d_j\cdot c\cdot x_j\right),$$

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Social Cost of Water Pollution

$$\text{Marginal social cost} = mWTP_j = \frac{[\partial V(\cdot)/\partial q_j][\partial q_j/\partial e]}{\partial V(\cdot)/\partial Y}$$

$$mSCWP = \sum_{k=1}^{J}\sum_{j=1}^{J} c_k \cdot \frac{\partial x_k(\cdot)}{\partial q_j}\frac{\partial q_j}{\partial e} + \frac{\sum_{j=1}^{J}\frac{\partial u_n^c}{\partial q}\frac{\partial q_j}{\partial e}}{\frac{\partial u_n^c}{\partial z}}$$

Recreation behavior

$$- \left[p_b \frac{\partial b(\cdot)}{\partial q_2}\frac{\partial q_2}{\partial e} + \tau'(q_2)\frac{\partial q_2}{\partial e} \right]$$

Drinking water: cost to clean plus substitute

$$+ \frac{\partial d_1(q_1)}{\partial q_1}\frac{\partial q_1}{\partial e}\frac{\partial P(\cdot)}{\partial d_1} - \frac{\partial P(\cdot)}{\partial q_1}\frac{\partial q_1}{\partial e} + c \cdot x_1 \frac{\partial d_1(q_1)}{\partial q_1}\frac{\partial q_1}{\partial e}$$

Housing Market

$$+ \sum_{j=1}^{J}\frac{\partial u_n^e}{\partial q_j}\frac{\partial q_j}{\partial e}$$

No market footprint – SP only

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Recreation Component

Marginal change in recreation expenditures + marginal changes in utility from site visits

$$\sum_{k=1}^{J}\sum_{j=1}^{J} c_k \cdot \frac{\partial x_k(\cdot)}{\partial q_j}\frac{\partial q_j}{\partial e} + \frac{\sum_{j=1}^{J}\frac{\partial u_n^c}{\partial q}\frac{\partial q_j}{\partial e}}{\frac{\partial u_n^c}{\partial z}}$$

Recreation demand models (RUM, demand systems, etc) can recover wtp for changes in water quality at recreation sites.

Drinking Water Component

Marginal change in bottled water purchases + marginal changes water cleaning

$$\left[p_b \frac{\partial b(\cdot)}{\partial q_2} \frac{\partial q_2}{\partial e} + \tau'(q_2) \frac{\partial q_2}{\partial e} \right]$$

No double counting problems give strong separability assumptions of the model

Hedonic Component

$$\left[\frac{\partial P(\cdot)}{\partial d_1}\frac{\partial d_1(q_1)}{\partial q_1}\frac{\partial q_1}{\partial e}-\frac{\partial P(\cdot)}{\partial q_1}\frac{\partial q_1}{\partial e}\right]+c\cdot x_1\frac{\partial d_1(q_1)}{\partial q_1}\frac{\partial q_1}{\partial e}$$

Marginal change in house price due to water quality improvement at q_1 - the change in recreation expenditures at the lake (to prevent double counting)

1. Estimate of hedonic price function can recover first component

2. Recreation demand can recover second.

Stated Preferences

$$\sum_{j=1}^{J} \frac{\partial u_n^e}{\partial q_j} \frac{\partial q_j}{\partial e}$$

1. Can we elicit existence values for water quality from SP?

2. Can we design SP instruments that will fully elucidate and capture all components/mechanism?

ADVERTISING

Atkinson Center Program:
The Social Cost of Water Pollution

GOALS:

1. Build a community of scholars interested in water quality
2. Promote a ‘big tent’ workshop – the place people go each year to present and learn about water quality research
3. Keep it multidisciplinary (economists, ecologists, hydrologists, etc.) and multisector (academics, government agencies, NGOs)
4. Promote progress on building durable IAMs for water quality valuation
5. Get to a point where we can do comparisons of common scenarios?

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Atkinson Center Program:
The Social Cost of Water Pollution
With Dan Phaneuf and Dave Keiser

Second Annual Meeting held in Ithaca in April, 2019

Attended by:

- Academic researchers (Cornell and across the world)
- State and federal agencies (EPA, USDA, NRCS)
- NGOs (TNC, RFF)
- Business interests

Third annual meeting to be held in Washington, DC tentatively targeting 22-24 April

Look for call for papers early fall

Thank You

Questions and Comments welcome

Support from the Atkinson Center, Cornell University and the US Environmental Protection Agency are much appreciated.

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