Recreation Demand Using Physical Measures of Water Quality

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Linking Recreational Values to Physical Water Quality

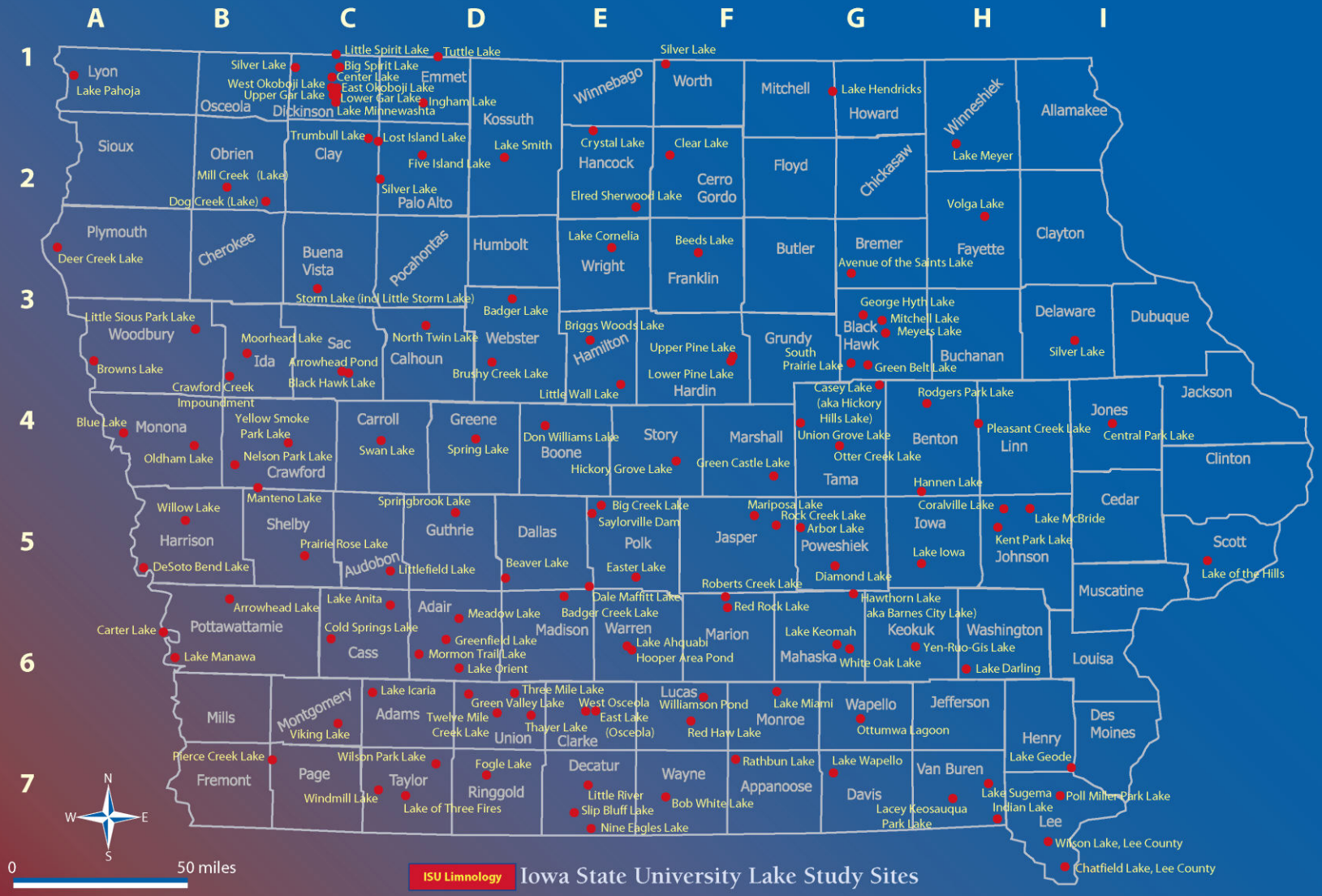
- Regulatory considerations, such as TMDL standards, require developing physical water quality standards.
- Yet the linkage between the physical measures of water quality and the values associated with water resources is poorly understood.
- Recreation demand models have found water quality matters, but have typically had to rely on limited measures, such as
  - Catch rates (e.g., Chen, Lupi, and Hoehn, 1999),
  - Toxin levels (Phaneuf, Kling and Herriges, 2000), or
  - Water quality indicators (Parsons, Helm, and Bondelid, 2003)
- Understanding the linkage between physical attributes and water quality values is important to
  - setting water quality standards
  - prioritizing restoration efforts

Iowa Lakes Valuation Project

- Collaborative project involving economists and ecologists studying Iowa lakes
  - Builds off of existing 5 year study of the ecological conditions of 132 lakes in Iowa (2000-2004)
- EPA Star grant augments work begun with Iowa DNR funding and CARD support – 4 year project
- A four-year panel data set of survey responses will be collected involving
  - Actual trip behavior and future expected trips, years 2001-2006
  - 2nd through 4th year survey will contain water quality scenarios measuring WTP for quality improvements
  - Knowledge and perceptions regarding lake quality

Baseline Survey

- First of four mail surveys
- 8000 Iowa residents selected at random
- Survey collected
  - trip data for 132 lakes
    - 2001 and 2002 actual trips
    - 2003 anticipated trips
  - attitudes regarding lake quality
  - Socio-demographic data
- 62.1% response rate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Lyon
Lake Pahoja
Silver Lake
Little Spirit Lake
Tuttle Lake
Big Spirit Lake
Center Lake
West Okoboji Lake
East Okoboji Lake
Upper Gar Lake
Lower Gar Lake
Ingham Lake
Lake Minnewashta
Osceola
Dickinson
Emmet
Kossuth
Winnebago
Worth
Silver Lake
Mitchell
Lake Hendricks
Howard
Winneshiek
Lake Meyer
Allamakee
Sioux
Obrien
Mill Creek (Lake)
Dog Creek (Lake)
Trumbull Lake
Lost Island Lake
Five Island Lake
Silver Lake
Palo Alto
Clay
Lake Smith
Crystal Lake
Hancock
Elred Sherwood Lake
Clear Lake
Cerro Gordo
Floyd
Chickasaw
Volga Lake
Fayette
Clayton
Plymouth
Deer Creek Lake
Cherokee
Buena Vista
Storm Lake (incl Little Storm Lake)
Pocahontas
Humbolt
Lake Cornelia
Wright
Beeds Lake
Franklin
Butler
Bremer
Avenue of the Saints Lake
Little Sioux Park Lake
Woodbury
Browns Lake
Crawford Creek Impoundment
Moorhead Lake
Ida
Sac
Arrowhead Pond
Black Hawk Lake
Calhoun
Badger Lake
North Twin Lake
Webster
Brushy Creek Lake
Briggs Woods Lake
Hamilton
Little Wall Lake
Upper Pine Lake
Lower Pine Lake
Hardin
Grundy
South Prairie Lake
George Hyth Lake
Mitchell Lake
Meyers Lake
Black Hawk
Green Belt Lake
Buchanan
Delaware
Silver Lake
Dubuque
Blue Lake
Monona
Oldham Lake
Yellow Smoke Park Lake
Nelson Park Lake
Crawford
Carroll
Swan Lake
Greene
Spring Lake
Don Williams Lake
Boone
Hickory Grove Lake
Story
Green Castle Lake
Marshall
Casey Lake (aka Hickory Hills Lake)
Union Grove Lake
Otter Creek Lake
Tama
Rodgers Park Lake
Benton
Pleasant Creek Lake
Linn
Jones
Central Park Lake
Jackson
Clinton
Willow Lake
Harrison
DeSoto Bend Lake
Manteno Lake
Shelby
Prairie Rose Lake
Springbrook Lake
Guthrie
Audobon
Littlefield Lake
Dallas
Beaver Lake
Big Creek Lake
Saylorville Dam
Polk
Easter Lake
Mariposa Lake
Rock Creek Lake
Arbor Lake
Jasper
Poweshiek
Diamond Lake
Hannen Lake
Coralville Lake
Iowa
Lake Iowa
Lake McBride
Kent Park Lake
Johnson
Cedar
Scott
Lake of the Hills
Muscatine
Arrowhead Lake
Carter Lake
Pottawattamie
Lake Manawa
Lake Anita
Cold Springs Lake
Cass
Adair
Meadow Lake
Greenfield Lake
Mormon Trail Lake
Lake Orient
Madison
Dale Maffitt Lake
Badger Creek Lake
Warren
Lake Ahquabi
Hooper Area Pond
Marion
Red Rock Lake
Roberts Creek Lake
Lake Keomah
Mahaska
Hawthorn Lake (aka Barnes City Lake)
Keokuk
Yen-Ruo-Gis Lake
White Oak Lake
Washington
Lake Darling
Louisa
Mills
Montgomery
Viking Lake
Lake Icaria
Adams
Twelve Mile Creek Lake
Green Valley Lake
Three Mile Lake
Union
West Osceola
East Lake (Osceola)
Thayer Lake
Clarke
Lucas
Williamson Pond
Red Haw Lake
Monroe
Lake Miami
Wapello
Ottumwa Lagoon
Jefferson
Henry
Lake Geode
Des Moines
Pierce Creek Lake
Fremont
Page
Windmill Lake
Wilson Park Lake
Taylor
Lake of Three Fires
Fogle Lake
Ringgold
Decatur
Little River
Slip Bluff Lake
Nine Eagles Lake
Wayne
Bob White Lake
Rathbun Lake
Appanoose
Lake Wapello
Davis
Van Buren
Lacey Keosauqua Park Lake
Lake Sugema
Indian Lake
Poll Miller Park Lake
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Wilson Lake, Lee County
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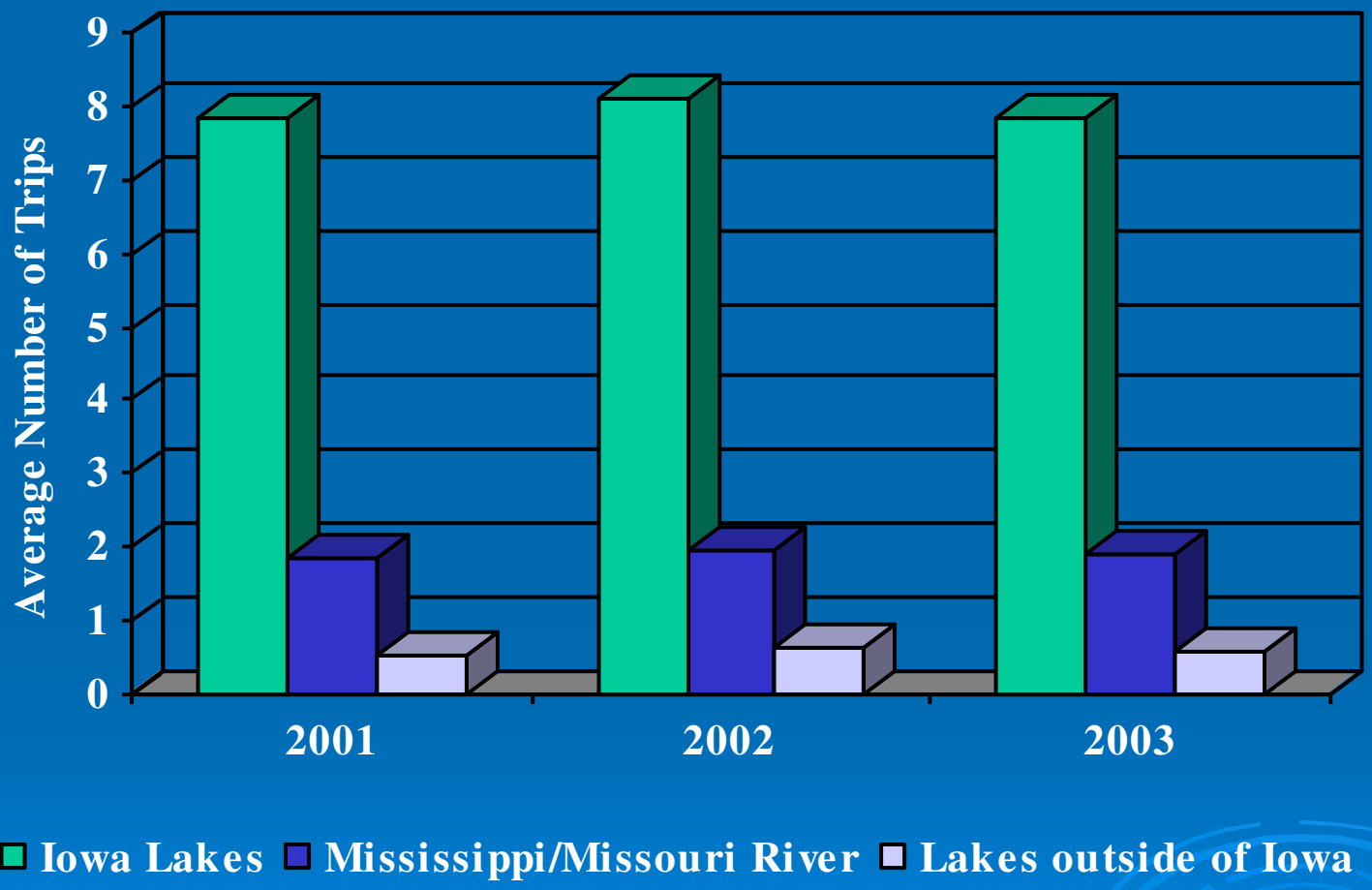
ISU Limnology
Iowa State University Lake Study Sites

Figure 2: Average number of day trips



62.8% of Iowa households took at least one trip

Summary Statistics

Table 2. Lake Characteristics Summary Statistics				
Variable	Mean	Std. Dev.	Minimum	Maximum
Day Trips per Individual	6.68	10.46	0	52
Price	135.79	29.47	94.12	239.30
Acres	672.20	2,120.30	10	19,000
Log(Acres)	4.81	1.69	2.30	9.85
Ramp	0.86	0.35	0	1
Wake	0.66	0.47	0	1
Handicap Facilities	0.39	0.49	0	1
State Park	0.39	0.49	0	1

Summary Statistics

Table 3. Physical Water Quality Summary Statistics				
Variable	Mean	Std. Dev.	Minimum	Maximum
Secchi Depth (m)	1.17	0.92	0.09	5.67
Chlorophyll (ug/l)	40.93	38.02	2.45	182.92
NH_3+NH_4 (ug/l)	292.15	158.57	72	955.34
NO_3+NO_2 (mg/l)	1.20	2.54	0.07	14.13
Total Nitrogen (mg/l)	2.20	2.52	0.55	13.37
Total Phosphorus (ug/l)	105.65	80.61	17.10	452.55
Silicon (mg/l)	4.56	3.24	0.95	16.31
pH	8.50	0.33	7.76	10.03
Alkalinity (mg/l)	141.80	40.98	73.83	286.17
Inorganic SS (mg/l)	9.43	17.87	0.57	177.60
Volatile SS (mg/l)	9.35	7.93	1.64	49.87

Modeling Issues

- Randomly divided sample into three segments:
  - Specification
  - Estimation
  - Prediction
- Modeling approach: repeated mixed logit
- Specification considerations
  - Inclusion/exclusion of specific water quality measures
  - functional form (e.g., linear, quadratic or logarithmic)
  - random versus fixed parameters

Repeated Mixed Logit

$$U_{ijt} = V(X_{ij}; \beta_i) + \varepsilon_{ijt}, \quad i = 1,...,1286; j = 0,...,129; t = 1,...,52.$$

Conditional on the parameter vector, β_i, the probability of observing that Individual *i* chooses alternative *j* on choice occasion *t* follows the standard logit form:

$$L_{ijt}(\beta_i) = \frac{\varepsilon xp\left(V_{ijt}(\beta_i)\right)}{\sum_{k=0}^{J} \varepsilon xp\left[V_{ikt}(\beta_i)\right]}$$

The corresponding unconditional probability, $P_{ijt}(\theta)$, is obtained by integrating over an assumed probability density function for the β_i's, assuming *i.i.d.* so that

$$P_{ijt} = \int L_{ijt}(\beta) f(\beta|\theta) d\beta$$

Specification

$$U_{ijt} = \begin{cases} \beta^{z'} z_i + \varepsilon_{i0t} \\ -\beta^{p} P_{ij} + \beta^{q'} Q_j + \beta_i^{a'} A_j + \alpha_i + \varepsilon_{ijt}, \quad j = 1, \ldots, J \end{cases}$$

where

z_i is the vector of socio-demographic data,

P_{ij} represents the computed travel cost or "price" of the recreation trip

calculated as: P_{ij} =.25*distance+$\frac{1}{3}$(travel time * wage),

Q_j represents the physical water quality measures for each lake,

A_j represents the attributes for each lake.

Coefficient Results

Variable	Using 6 physical WQ measures	
	Mean	*Dispersion*
Income	-0.06	
Male	**-5.79**	
Age	**-0.35**	
Age^2	-0.0004	
School	**-2.61**	
Household	**-2.50**	
Price	**-0.48**	
Log(Acres)	**4.38**	**3.75**
Ramp	**11.14**	**18.86**
State Park	**3.83**	**14.86**
Facilities	**0.80**	**14.40**
Wake	**2.43**	**10.48**
α	**-12.24**	**2.44**

Variable	Using 6 Physical WQ measures
Secchi Depth	**0.87**
Chlorophyll	**0.61**
Total Nitrogen	-0.15
Total Phosphorus	**-2.51**
Inorganic SS	**-0.73**
Volatile SS	-0.20

Comparing Water Quality across Lakes

	West Okoboji Lake	Averages of the nine focus lakes	Medians of the non-impaired lakes	Averages of the 65 impaired lakes
Secchi Depth (m)	5.67	1.23	0.90	0.70
Chlorophyll	2.63	40.13	6.55	56.76
Total Nitrogen	0.86	3.64	1.10	2.77
Total Phosphorus	21.28	91.11	43.87	153.70
Inorganic Suspended Solids	1.00	9.52	5.42	20.42
Volatile Suspended Solids	1.79	8.42	3.62	15.49

Silver Lake

West Okoboji Lake

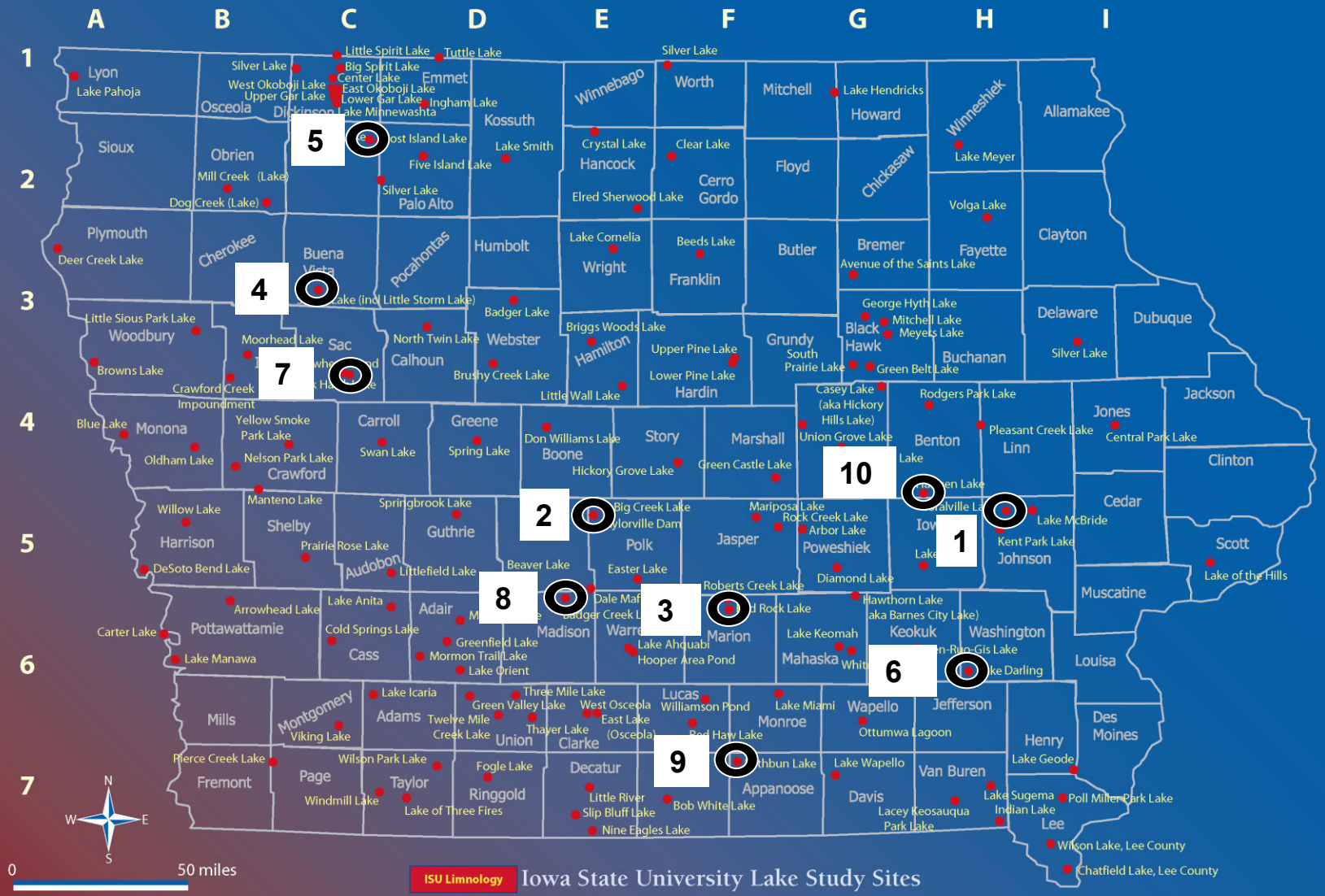
Willingness to Pay Estimates

Average Annual WTP	Nine focus lakes improved to West Okboboji	Sixty-five impaired lakes improved to the median of the non-impaired lakes
Per Iowa household	$11.86	$10.23
for all Iowa households	$13,675,685	$11,799,261
Predicted Trips (8.0 currently)	8.3	8.2

Willingness to Pay Estimates

Lakes with the Highest Valued Improvements						
Lake	On EPA's Impaired Waters List	Annual WTP	Secchi Depth (m)	Total Phosphorus (ug.l)	Total Annual 2002 Day Trips	Average Travel Cost
Coralville Lake	Yes	$10,600,000	0.8	204	457,000	$106
Saylorville Lake	No	$6,000,000	0.7	101	600,000	$97
Red Rock Lake	No	$3,700,000	1.5	99	284,000	$112
Storm Lake	Yes	$1,100,000	0.5	89	232,000	$157
Trumbull Lake	Yes	$900,000	0.1	453	20,000	$168
Lake Darling	Yes	$800,000	0.3	226	63,000	$124
Black Hawk Lake	Yes	$800,000	0.9	193	99,000	$138
Badger Creek Lake	Yes	$800,000	0.6	290	63,000	$104
Rathbun Lake	No	$600,000	0.9	44	248,000	$139
Hannen Lake	No	$500,000	1.3	227	41,000	$101
Average across all lakes		$300,000	1.2	106	83,000	$136

Figure 8: Lake zones

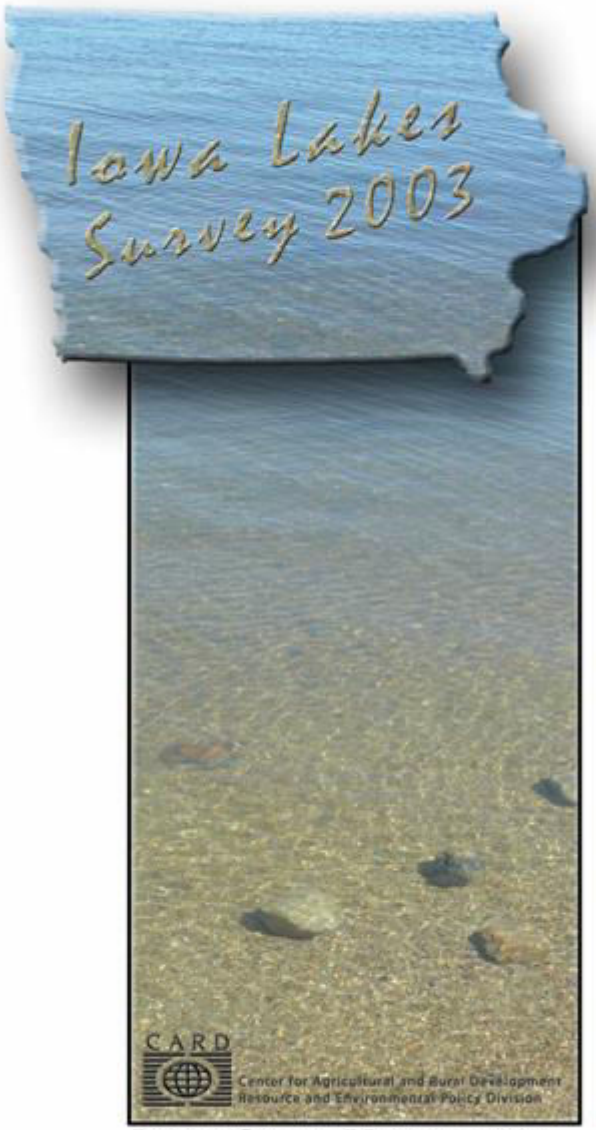


Conclusions

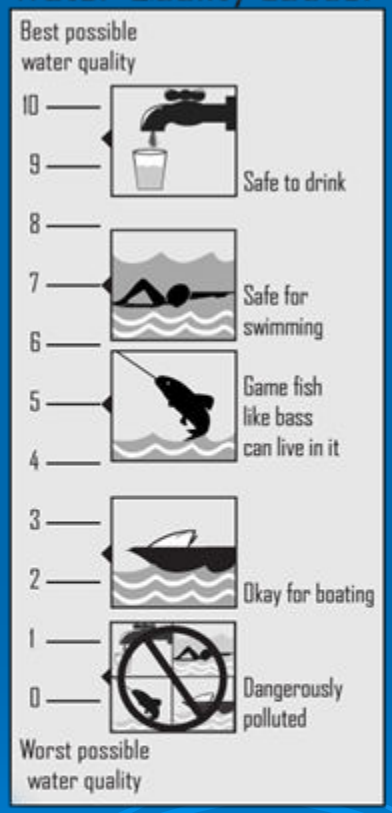
- Recreator's trip behavior is responsive to physical measures of Water Quality
  - Better water clarity increases recreational trips
  - Nutrients decrease recreational trips
- Allows consumer surplus measures to directly be linked to physical water quality improvements
  - Iowans value more highly a few lakes with superior water quality over all recreational lakes at an adequate level
- Findings allow prioritization for clean-up activities to generate the greatest recreation benefits for a given expenditure
  - Rank which lakes and in what order and most efficient levels of improvement

Next Stages of Project

- 2003 Survey gathered
  - A second year of trip data
  - Perceptions data regarding water quality
  - Stated preference data regarding water quality improvements
- 2004 Survey is currently in development


Iowa Lakes
Survey 2003
CARD
Center for Agricultural and Rural Development
Resource and Environmental Policy Division
IOWA STATE UNIVERSITY
DEPARTMENT OF ECONOMICS

Name of Lake (County)	Check if you have ever considered visiting this lake	Number of visits (January-December) in 2003		Water Quality Assessment
		Single-Day	Over-night	
Arbor Lake (Poweshiek)				
Arrowhead Lake (Pottawattamie)				
Arrowhead Pond (Sac)				
Avenue of the Saints Lake (Bremer)				
Badger Creek Lake (Madison)				
Badger Lake (Webster)				
Beaver Lake (Dallas)				
Beeds Lake (Franklin)				
Big Creek Lake (Polk)				
Big Spirit Lake (Dickinson)				
Black Hawk Lake (Sac)				
Blue Lake (Monona)				
Bob White Lake (Wayne)				
Wood (Hamilt				

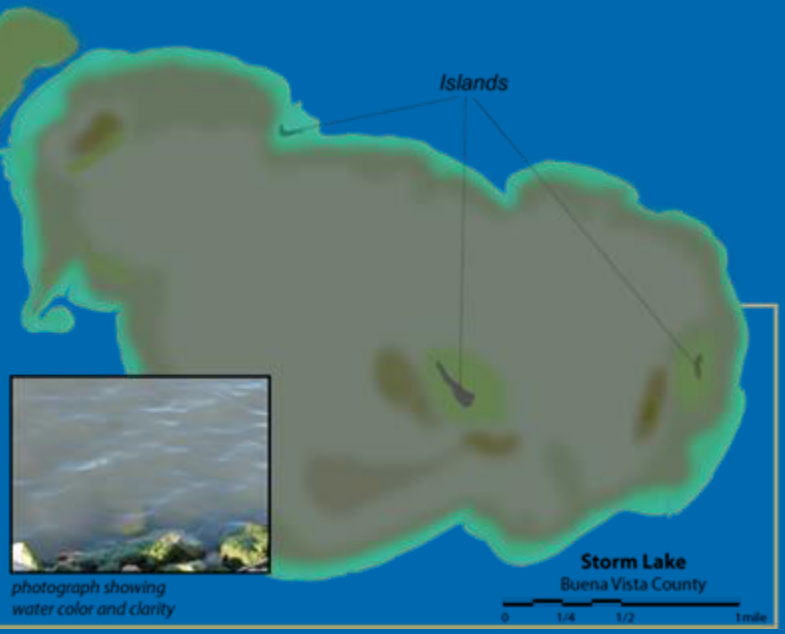


Water Quality Perceptions

	Full Sample		Water Contact		Non Water Contact	
	Corr.	p-value	Corr.	p-value	Corr.	p-value
Day Trip Per Capita	0.25	0.00	0.26	0.00	-0.10	0.24
Secchi Depth	0.42	0.00	0.43	0.00	0.13	0.13
Chlorophyll	-0.30	0.00	-0.29	0.00	-0.16	0.08
NH3+NH4	-0.24	0.01	-0.23	0.01	-0.11	0.20
NO3NO2	-0.04	0.67	-0.03	0.75	-0.15	0.09
Total Nitrogen	-0.19	0.03	-0.18	0.04	-0.20	0.02
Total Phosphorus	-0.33	0.00	-0.32	0.00	-0.25	0.00
Silicon	-0.40	0.00	-0.39	0.00	-0.27	0.00
pH	-0.09	0.29	-0.10	0.23	0.03	0.75
Alkalinity	-0.20	0.02	-0.21	0.02	-0.13	0.13
ISS	-0.33	0.00	-0.34	0.00	-0.10	0.26
VSS	-0.38	0.00	-0.38	0.00	-0.15	0.10

Current conditions of Storm Lake can be summarized as:

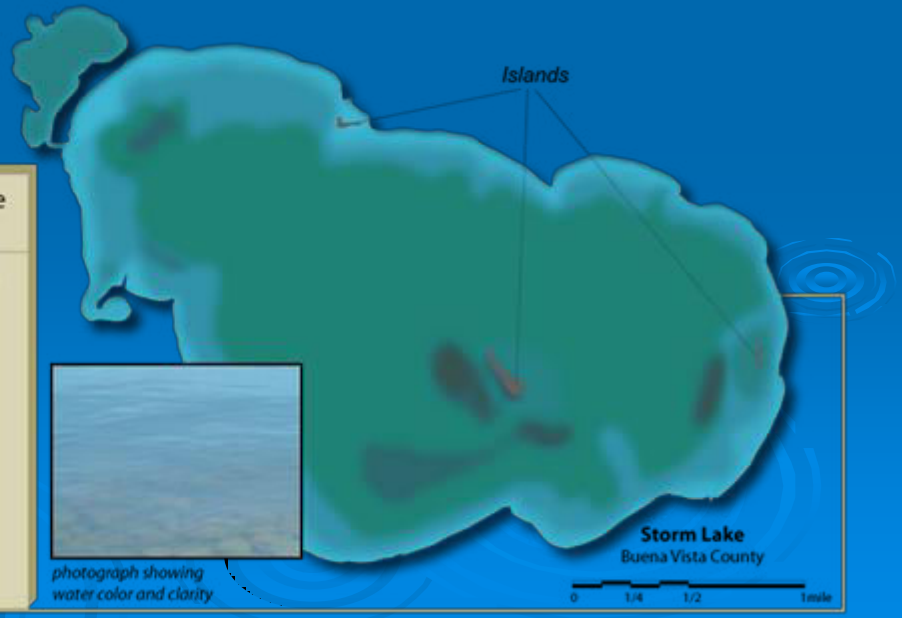
Water Clarity:	objects distinguishable 8 inches to 3 feet under water
Algae blooms:	2 to 5 per year
Water color:	brown to green
Water odor:	mild to strong odor
Bacteria:	possible short-term swim advisories
Fish:	low diversity



photograph showing water color and clarity

Improved conditions of Storm Lake can be summarized as:

Water Clarity:	objects distinguishable 6 to 8 feet under water
Algae blooms:	Rarely more than 1 per year
Water color:	green to blue
Water odor:	usually fresh
Bacteria:	rare swim advisories (most years none)
Fish:	high diversity



photograph showing water color and clarity