Social Demand and Cross-Scale Interactions in Riverine Social-Ecological Systems

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Texas State University

TEXAS STATE UNIVERSITY
The rising STAR of Texas

THE CITY OF SAN MARCOS

pecs WaterSES

SAN MARCOS GREENBELT ALLIANCE

smrf
San Marcos River Foundation


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Odessa
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Chihuahua
Monterrey
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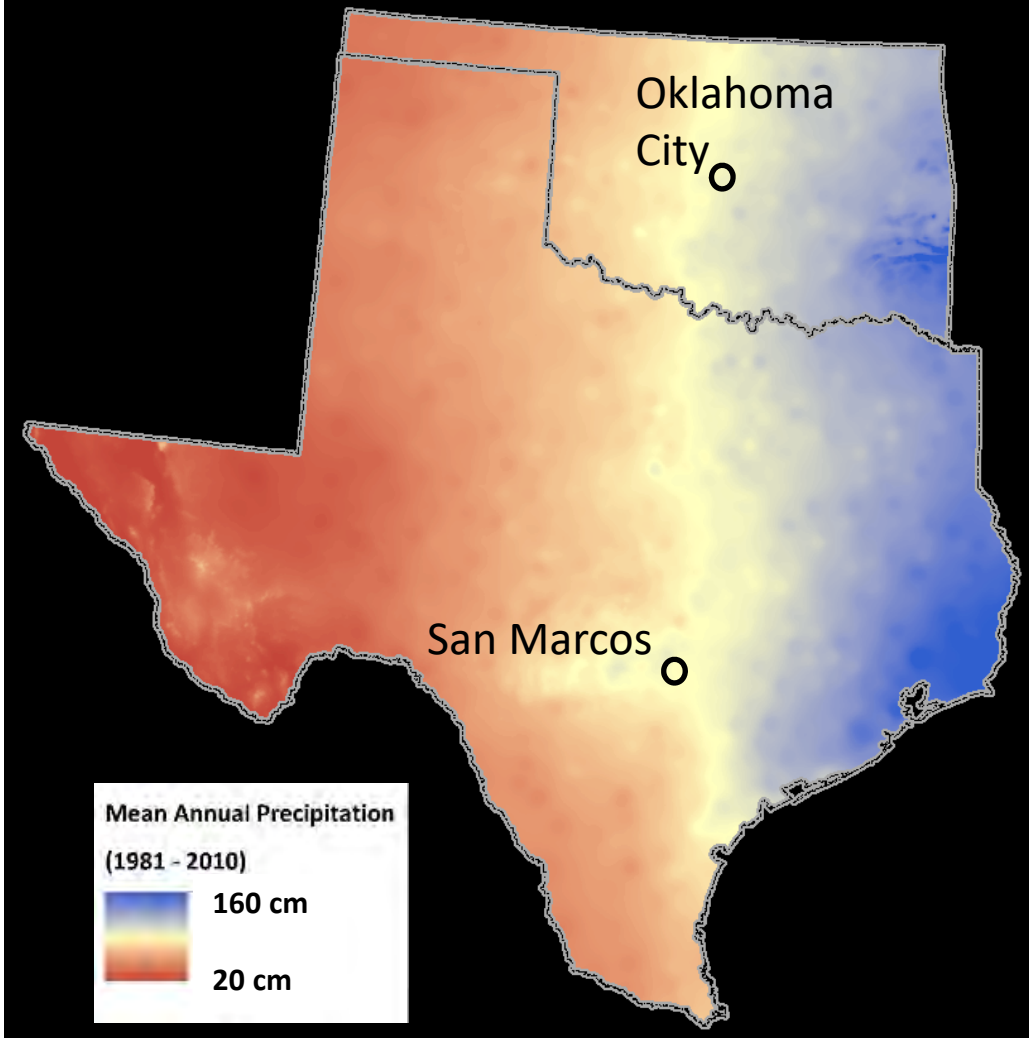
COAHUILA
NUEVO LEON
NAVAJO NATION
FORT APACHE RESERVATION

Two water-limited environments that depend on two valuable rivers



Kiamichi River, OK

San Marcos River, TX

Ecosystem Services

- the benefits that humans obtain from healthy ecosystems (Millennium Ecosystem Assessment, 2005)
- " a way of understanding the complex relationships between nature and humans to support decision-making, with the aim of reversing the declining status of ecosystems and ensuring the sustainable use/management/conservation of resources." (Martin-Ortega et al., 2015)
- an emerging framework that is being implemented across the globe and provides a tool to connect policy, economics, planning, and the environment

ECOSYSTEM SERVICES CLASSIFICATION

PROVISIONING

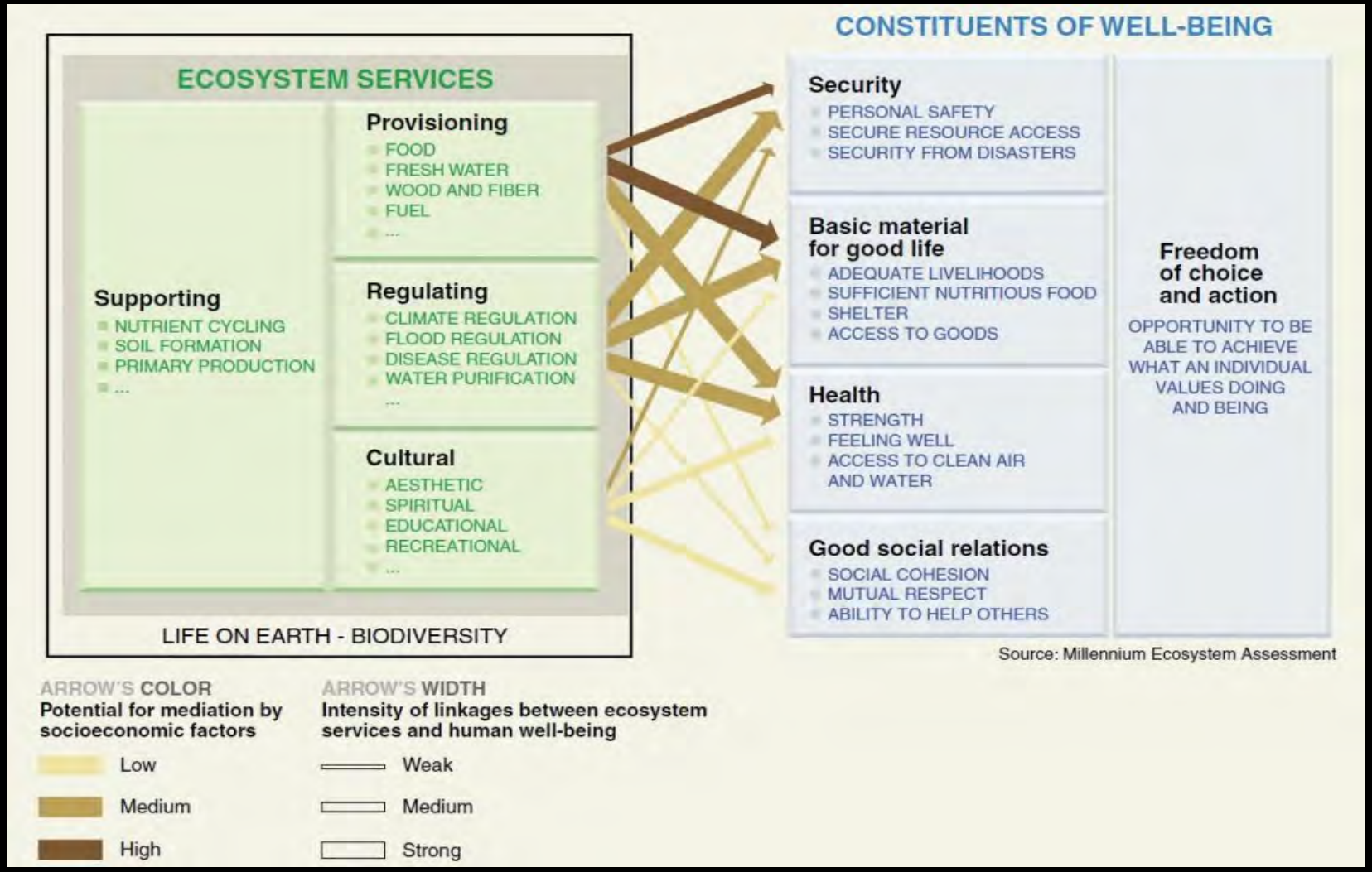
Direct products obtained by ecosystems

REGULATING

Indirect benefits obtained by ecological processes

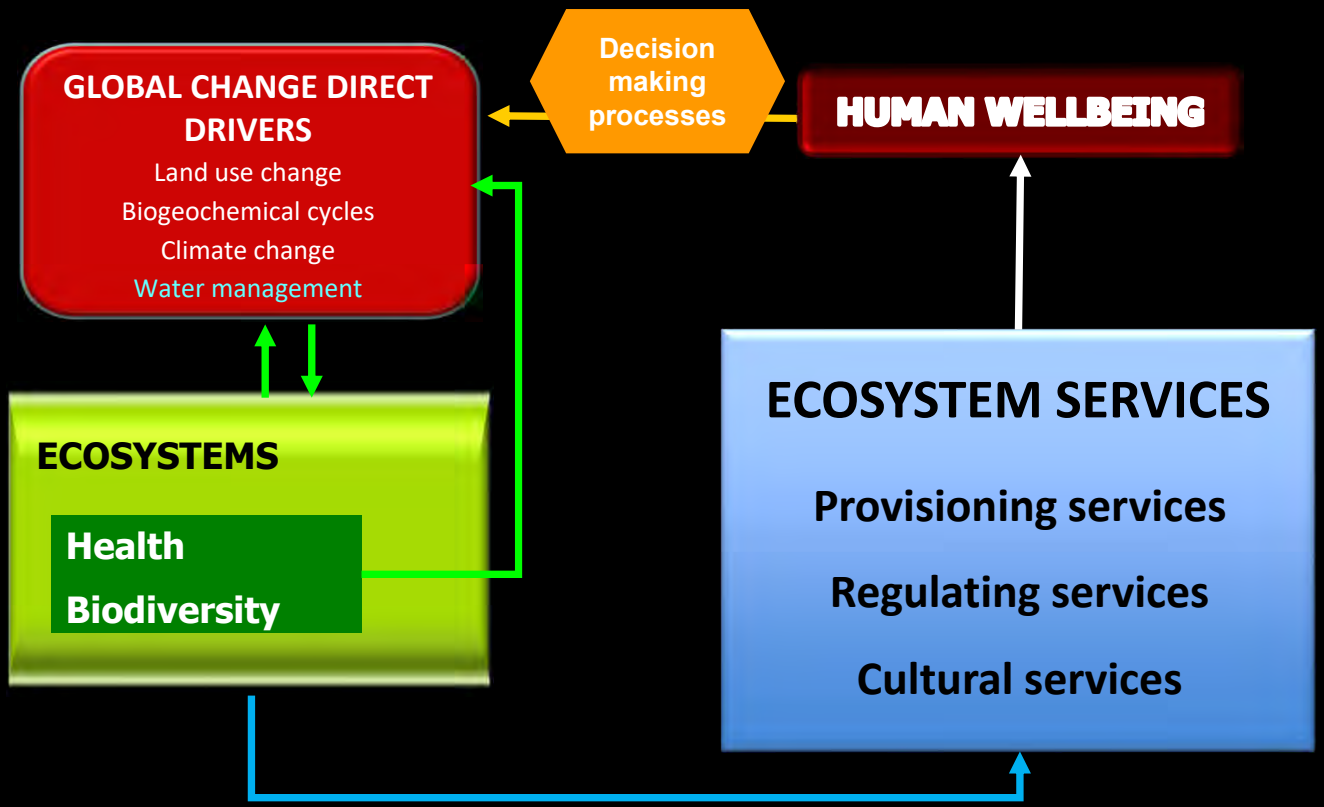
CULTURAL

Non-material benefits obtained through experiences

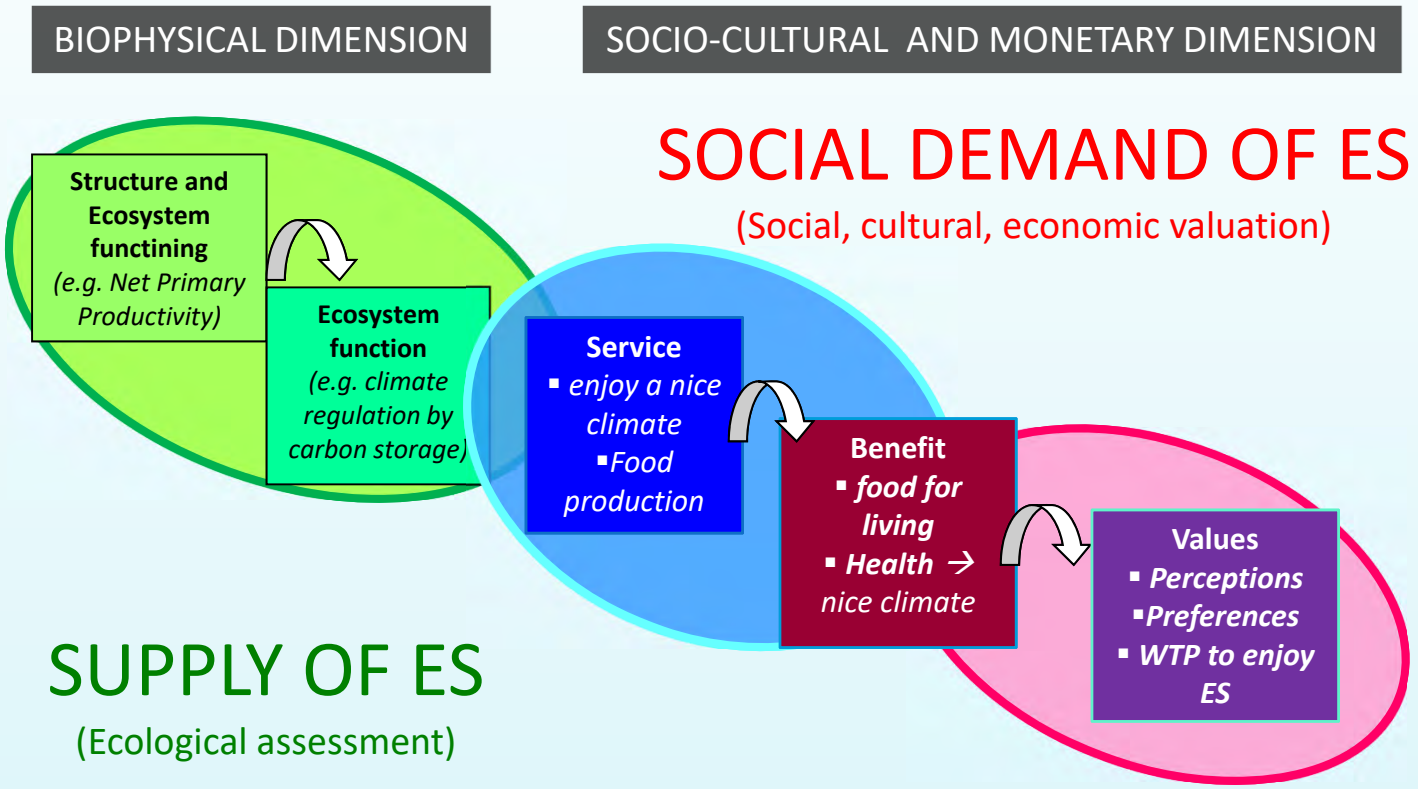


A framework to examine tradeoffs

Ecosystem Services assessment is both a conceptual framework and a planning tool



ECOSYSTEM SERVICES (ES) CASCADE

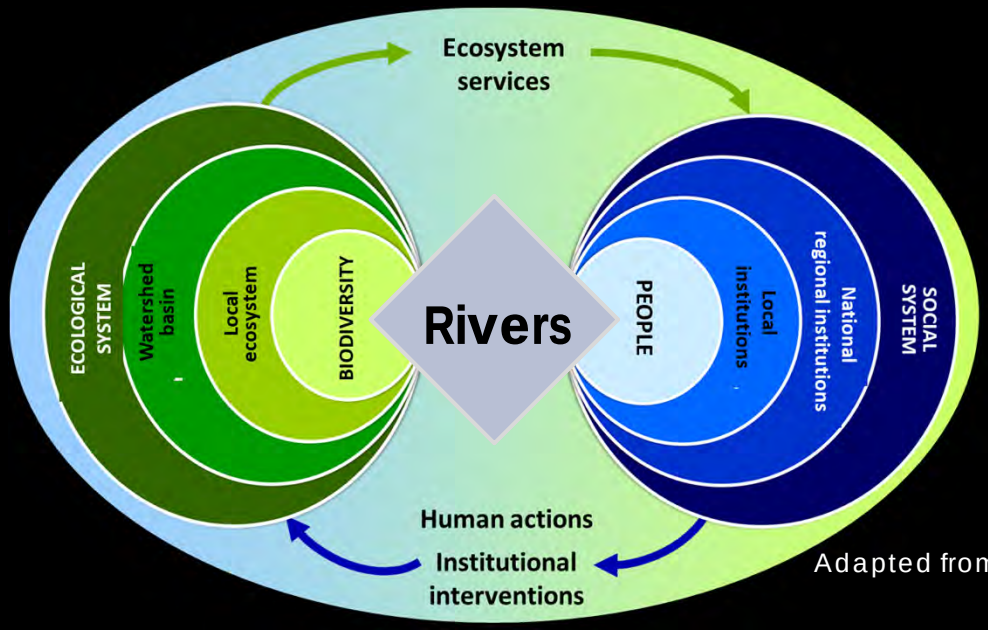


Potschin and Haines-Young (2011); Martín-López et al. (2014)

Social Demand

- Collective term for people's behavior/use, preferences, perceptions, and values (Martín-López et al., 2012; Julian et al., 2018)
- Based upon a range of social contexts (Cebrián-Piqueras et al., 2017; Wei et al., 2017; Tzoulas et al., 2007), from the individual to the collective community, and possibly across broader scales
- Difficult to assess; requires primary data (census; numerous, well-planned survey questionnaires) and secondary data (census; demographics; land use)

Rivers as Social-Ecological Systems



Adapted from Martin-Lopez et al. 2009

1. a coherent system of biophysical and social factors that regularly interact;
2. a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;
3. a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and
4. a perpetually dynamic, complex system with continuous adaptation

(adapted from Redman et al. 2004; Burch and DeLuca 1984; Machlis et al. 1997)

Cross-Scale Interactions (CSI)

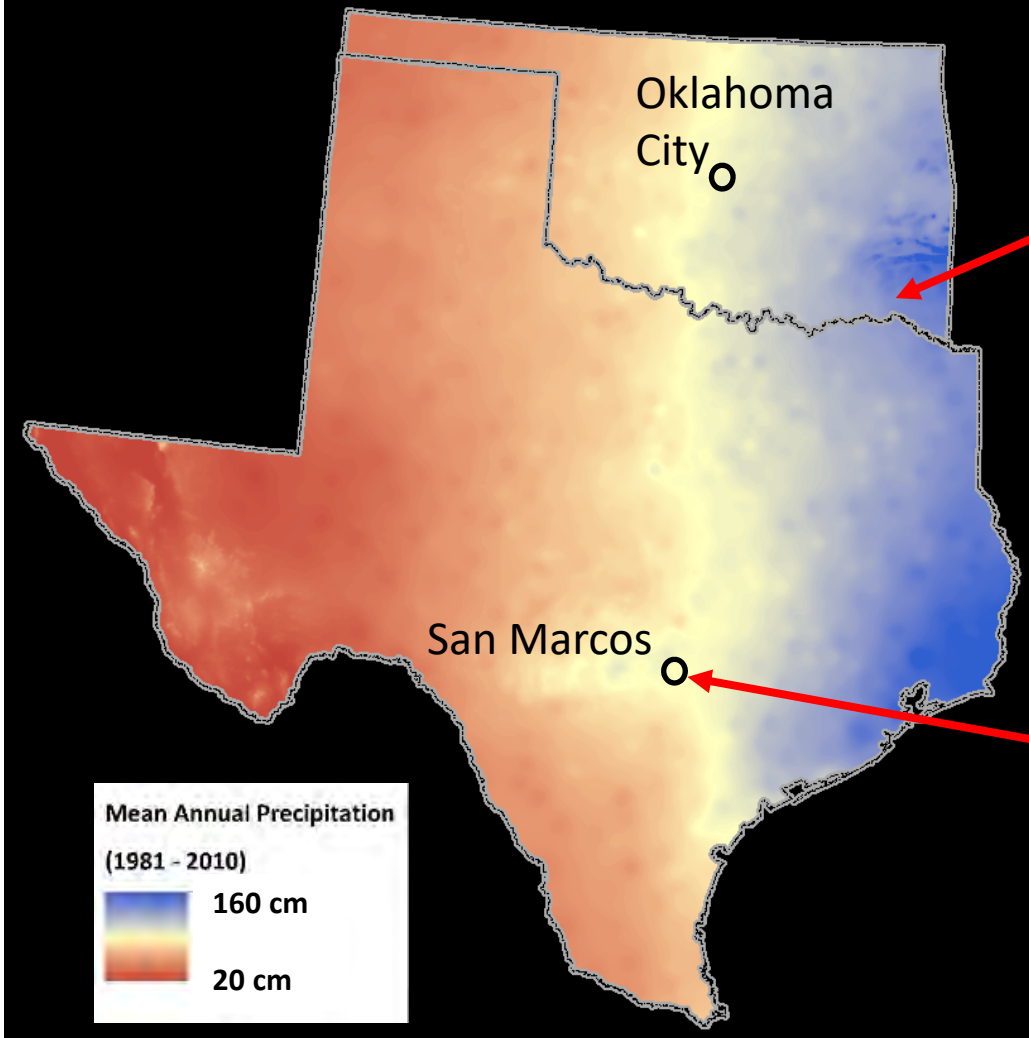
occur when processes or activities at one spatial or temporal scale interact with processes at finer or broader scales. In systems where CSI are connected, a change in an environmental driver (e.g. climate or land use) can result in process linkages and feedbacks that lead to changes in system dynamics (tipping points) or resilience.

Carpenter and Turner (2000), *Ecosystems*

Peters et al. (2007), *Ecosystems*

Julian et al. (2011), *Ecohydrology*

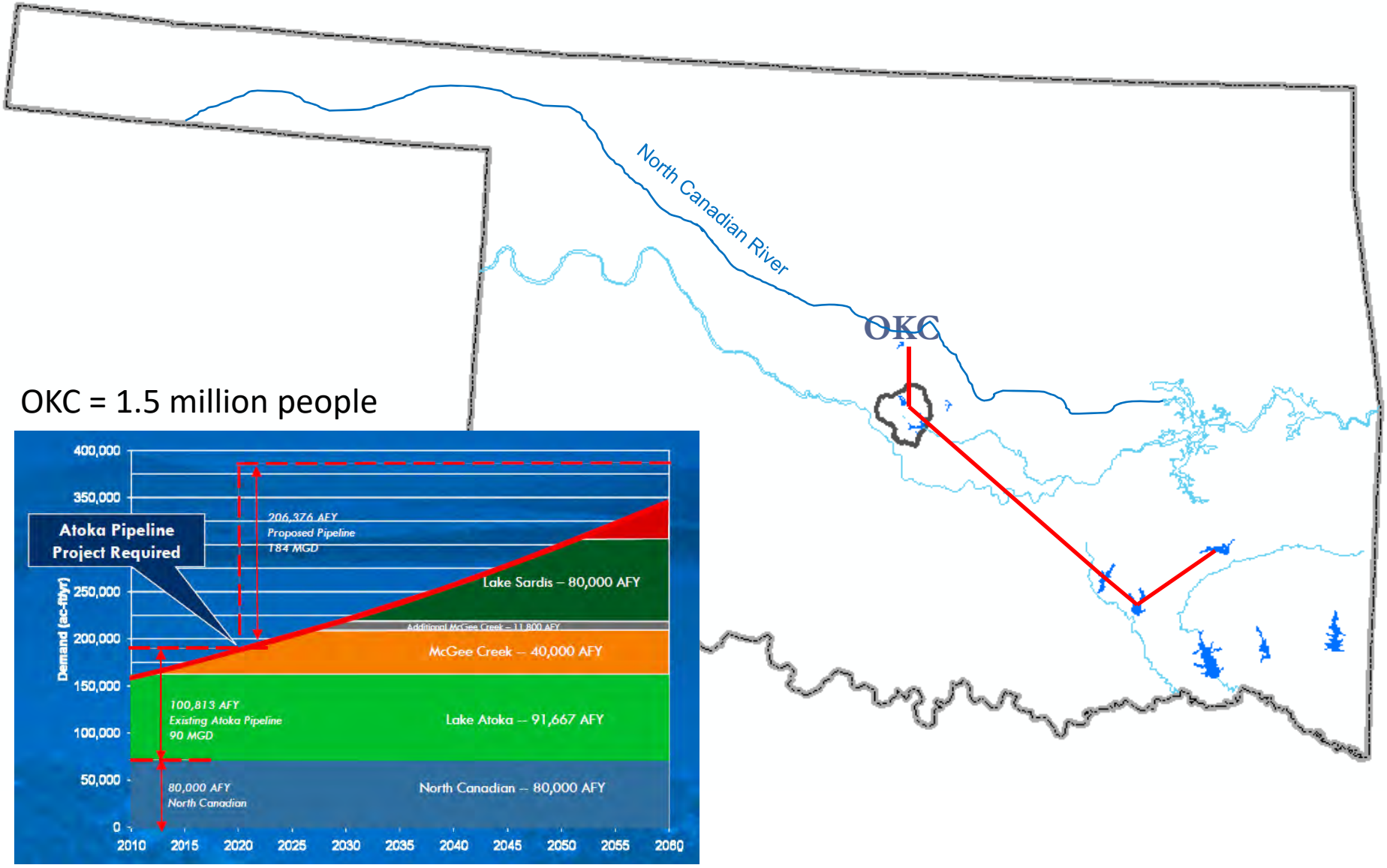
Two social-ecological systems (SES) that depend on two valuable rivers



Kiamichi River, OK

San Marcos River, TX

Oklahoma City's water sources



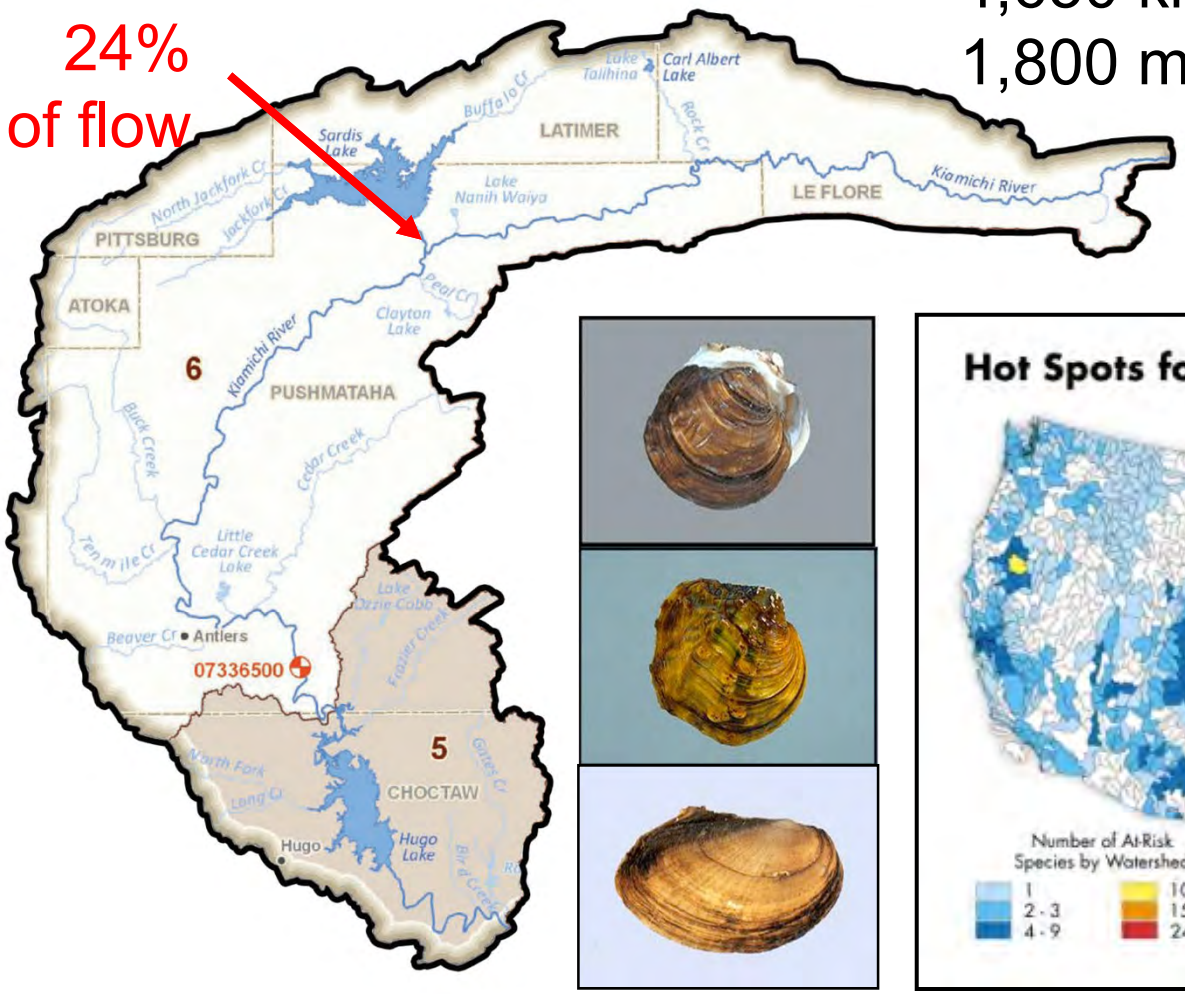
OKC = 1.5 million people

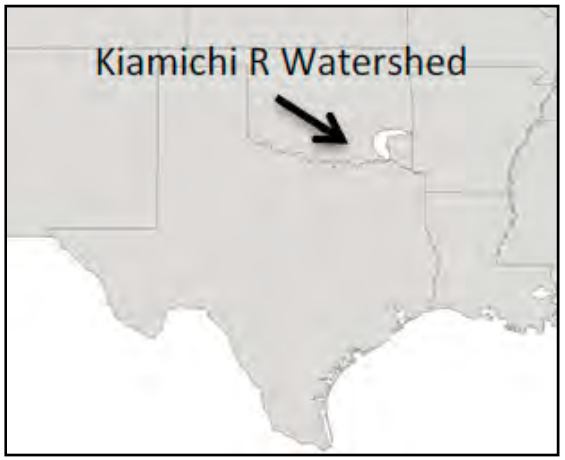
KIAMICHI RIVER WATERSHED IN SE OKLAHOMA

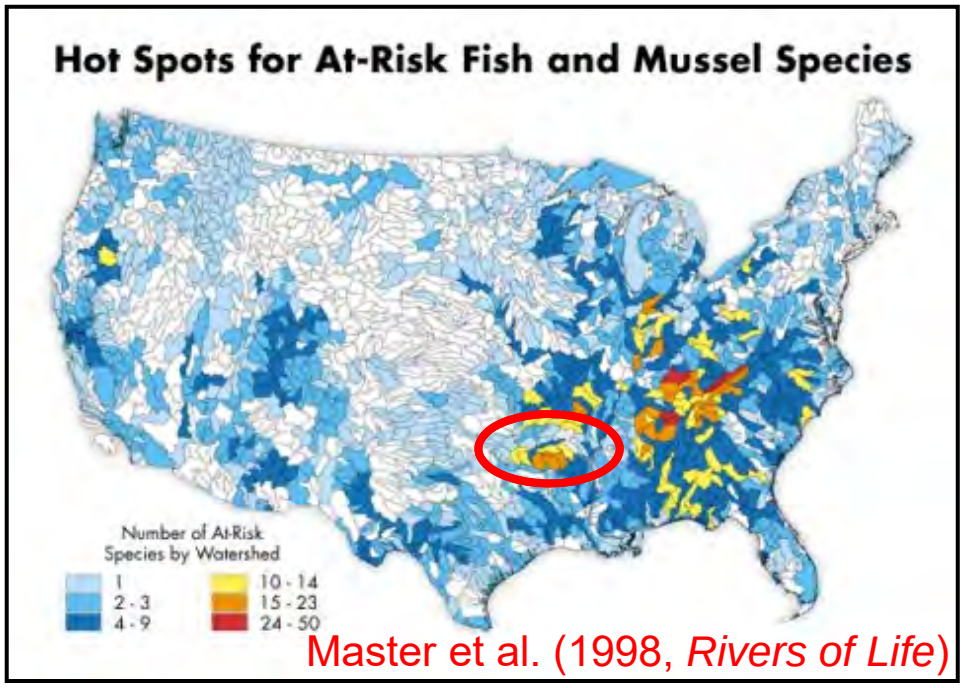
Kiamichi River

4,650 km^2
1,800 mi^2

24% of flow







Master et al. (1998, *Rivers of Life*)

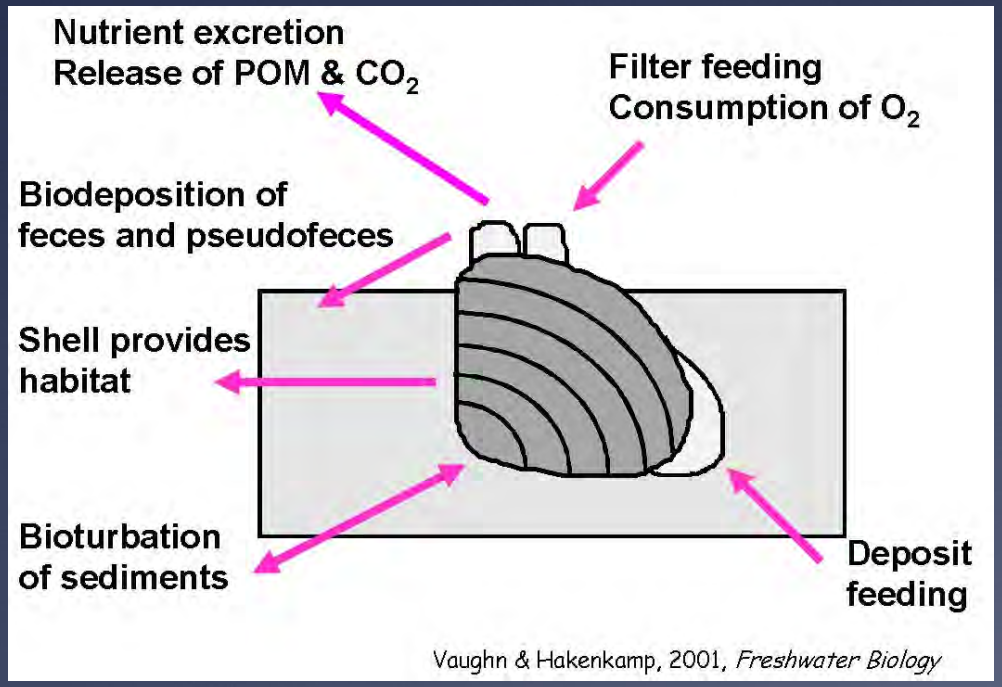
86 fish species

31 mussel species (56% of OK's mussel fauna)

3 federally-listed mussel species

FW Mussels are important and valuable

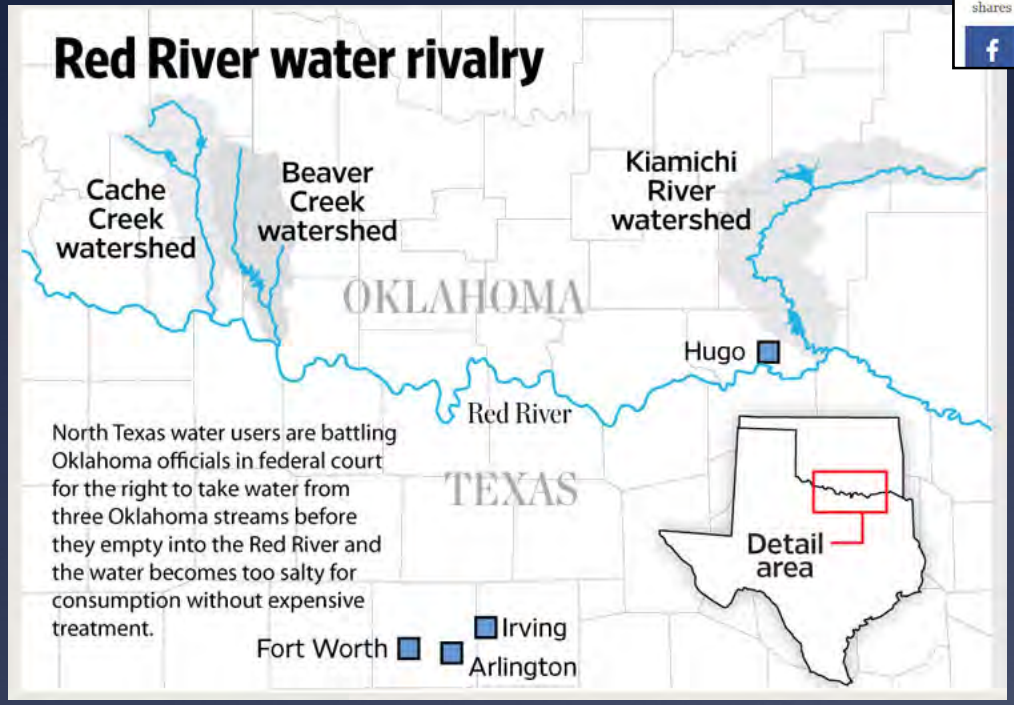
- Water purification (biofiltration)
- Nutrient recycling & storage
- Structural habitat
- Substrate modification
- Food for other organisms



"canaries of the rivers"

- Long-lived (6 – 100 yrs)
- Occur as dense, multispecies aggregations (mussel beds)

Kiamichi River water conflict



Board grants OKC permit for Kiamichi water

by William Crum · Published: October 12, 2017 5:00 AM CDT · *Updated: October 12, 2017 5:00 AM CDT*

10 shares

Oklahoma City is closer to securing water needed to sustain long-term growth — but a decision to grant a permit for southeastern Oklahoma water did not sit well with some residents of the region.

Water flows over the spillway at Hugo Lake, on the Kiamichi River, in southeastern Oklahoma. **Hugo Daily News archive photo**

FORT WORTH

Cash-strapped Oklahoma again floats idea of selling water to Texas

BY BILL HANNA
billhanna@star-telegram.com
MAY 12, 2017 12:18 PM

- Water used by many for a range of purposes
- Sardis Lake water co-managed by Oklahoma City (water supply), Choctaw Nation (recreation), and USACE (flood control)
- Potential water source for N TX

Willingness to Pay for Ecosystem Services among Stakeholder Groups in a South-Central U.S. Watershed with Regional Conflict

Antonio J. Castro, Ph.D.[1]; Caryn C. Vaughn, Ph.D.[2]; Marina García-Llorente, Ph.D.[3]; Jason P. Julian, Ph.D.[4]; and Carla L. Atkinson, Ph.D.[5]

Lake recreation is prioritized, resulting in no/low releases during dry summers

SITE 7: 2011 drought

- 19 species of freshly dead mussels
- 66 kg dry mussel soft tissue loss

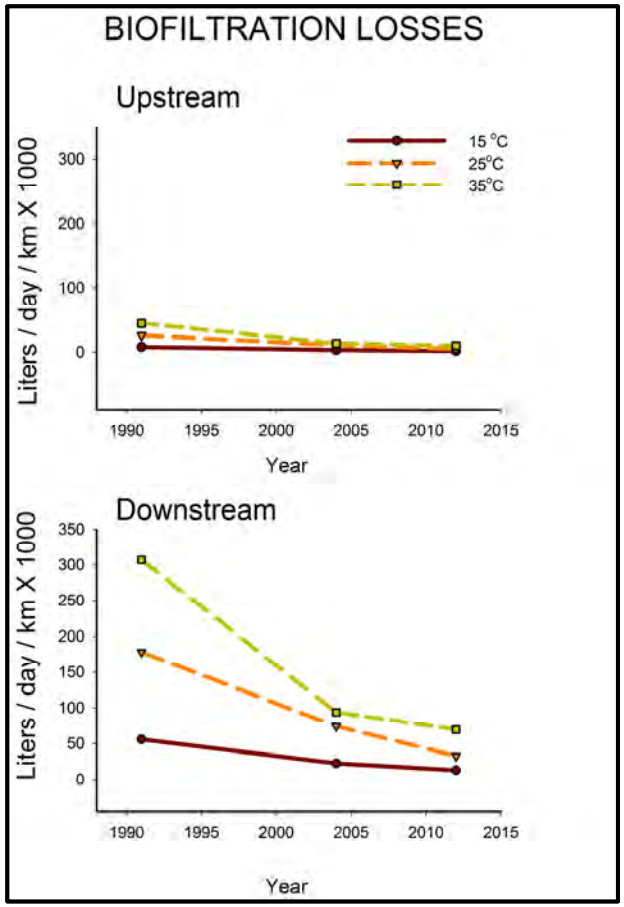
Average water depth
10 cm (4 inches)

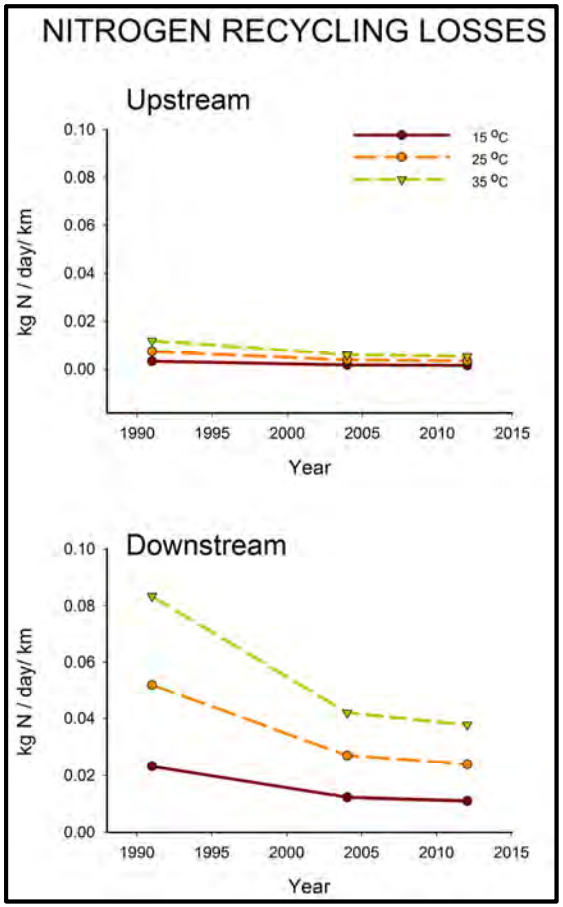
Water temp at midday
40 ° C (104 ° F)

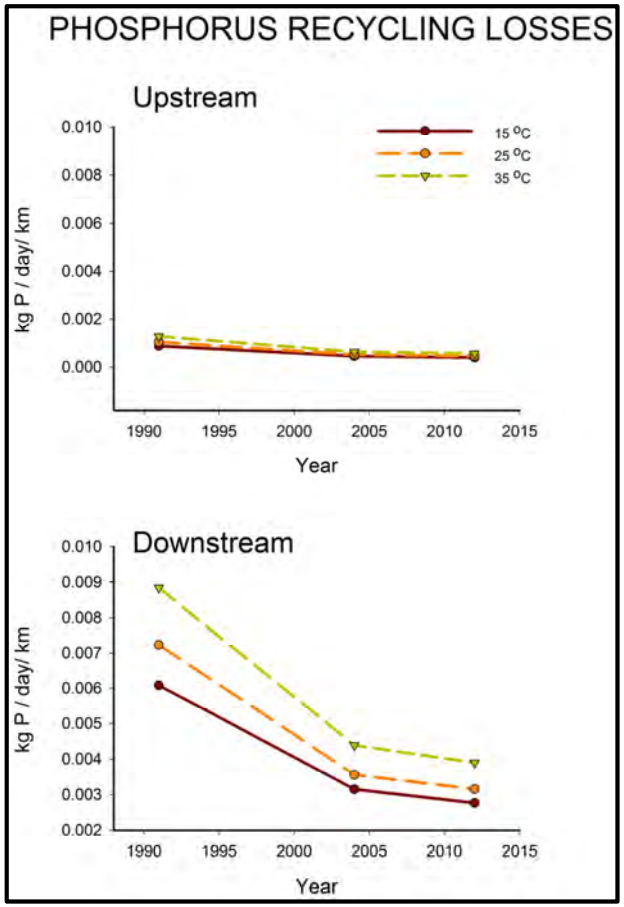
Temperature-induced mussel die offs lead to algal blooms,
low oxygen, and more death

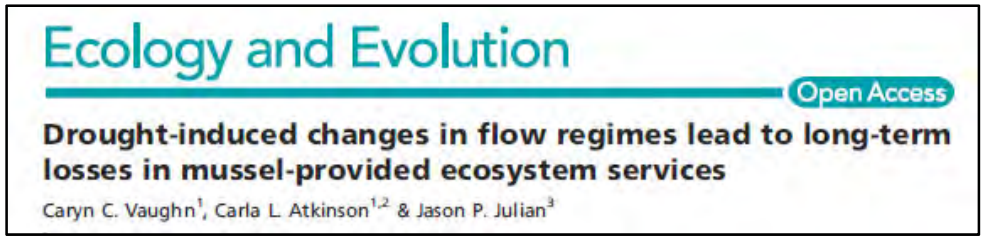
Which ES are we losing and how does that affect social demand?

Impact of flow releases on ES









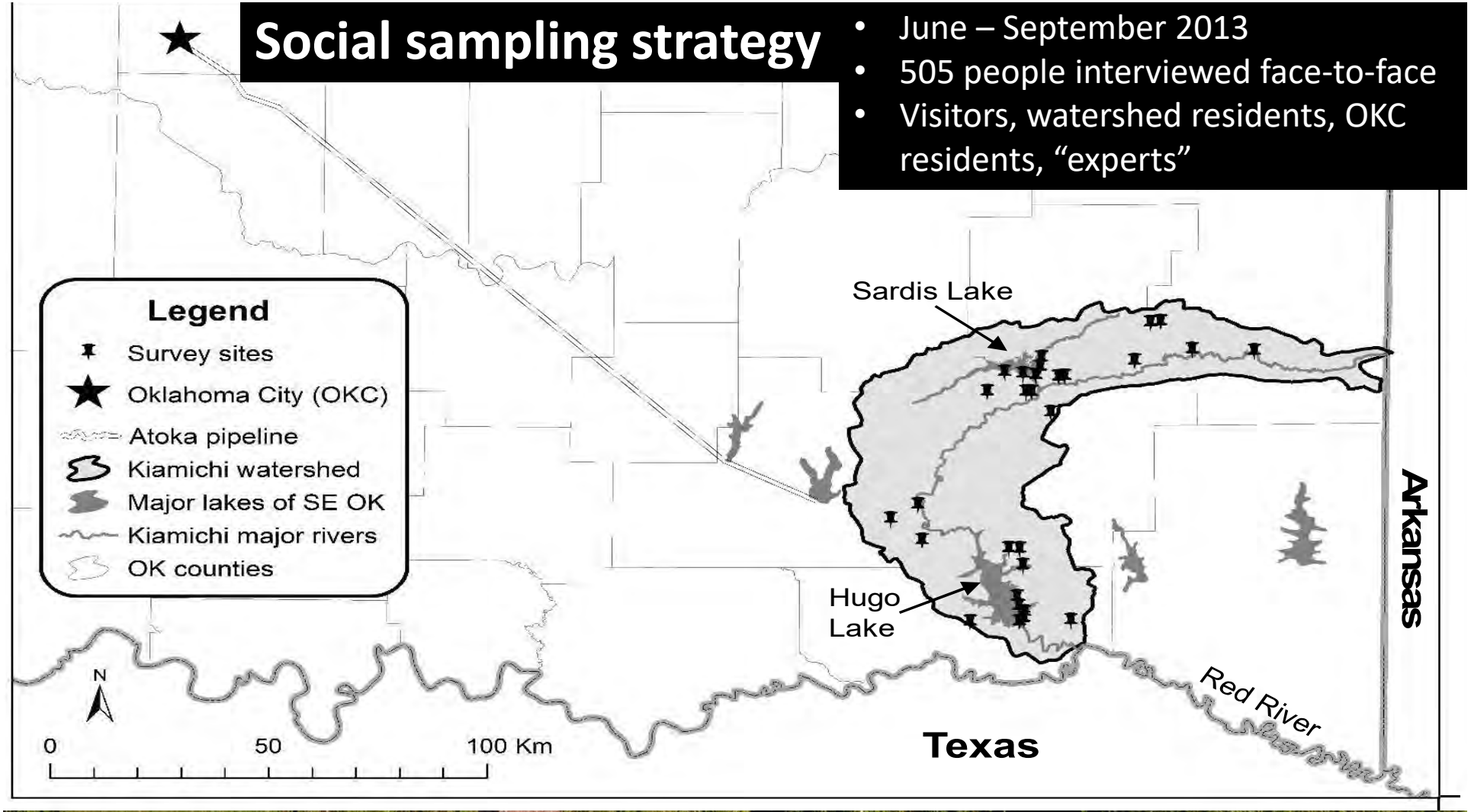
VALUE OF SERVICES PROVIDED BY THE KIAMICHI RIVER UNDER FOUR WATER FLOW SCENARIOS

Approach:

(1) Map the social-ecological system of the watershed
(2) Determine the most valuable watershed services
(3) Map the biophysical delivery of ecosystem services
(4) Identify and classify service beneficiaries
(5) Explore social and economic demand
(6) Analyze mismatches between supply and demand

Social sampling strategy

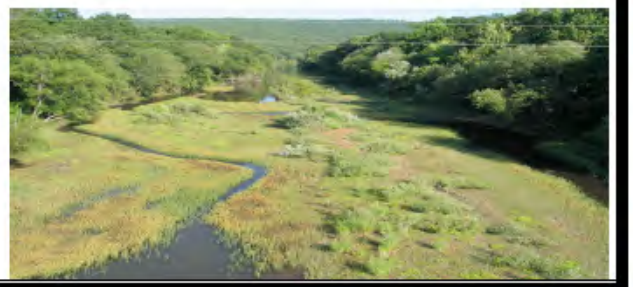
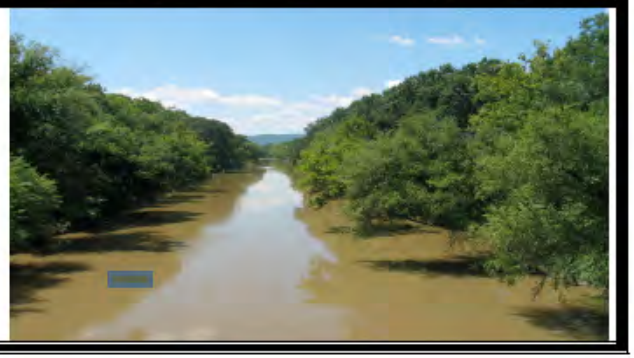
- June – September 2013
- 505 people interviewed face-to-face
- Visitors, watershed residents, OKC residents, “experts”



METHODS: People interviewed were shown these panels

DIRECT CONTRIBUTIONS OBTAINED FROM ECOSYSTEMS			INDIRECT CONTRIBUTIONS OBTAINED FROM THE FUNCTIONING OF NATURE			NON MATERIAL CONTRIBUTIONS THROUGH EXPERIENCES		
PROVISIONING			REGULATING			CULTURAL		
Benefit	Example	Pictures	Benefit	Example	Pictures	Benefit	Example	Picture
Fresh water provision	Rivers provide water for human consumption and use		**Water regulation**	Watersheds help to regulate the quality and quantity of water available for human (e.g. riparian vegetation helps regulate the water cycle)		**Recreation**	Rivers provide experiences through fishing or canoeing activities	
			Habitat for species	Rivers provide habitat for other species, e.g. catfish or deer		**Cultural heritage**	Southeast Oklahomans are proud of their culture	
			Water quality	Rivers species' purify water for human use, e.g. mussels filter water and make it more clear		**Local identity**	Oklahomans are very proud of where they come from	 
			Air quality	Forests maintain the quality of air (e.g. the role of ecosystems in the carbon storage)				

And then asked questions based on 4 water flow scenarios

Water flow scenarios	Pictures
No water flow	
Low water flow	
High water flow	
Flood	

SOCIAL DEMAND QUESTIONS

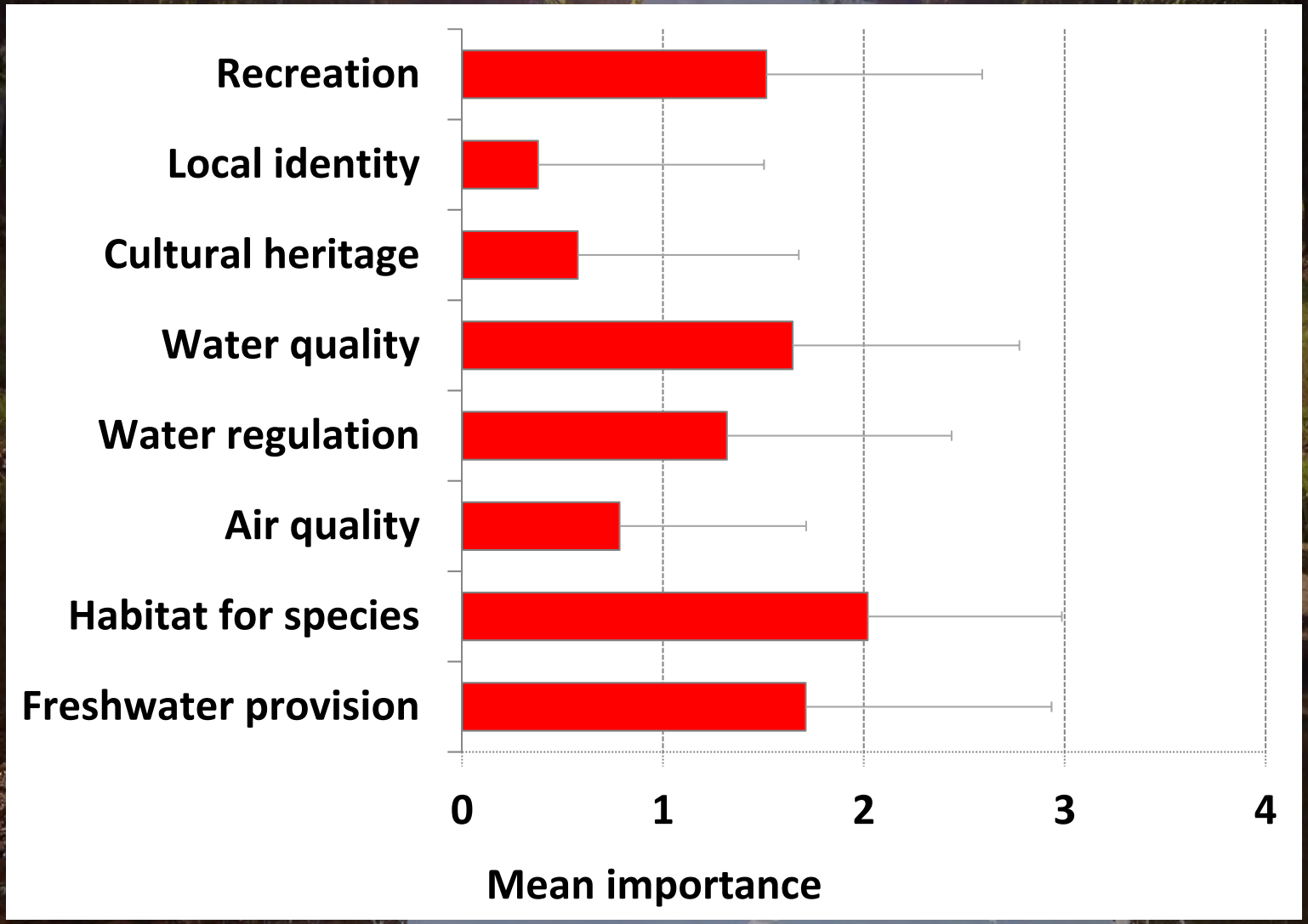
1. General public opinion on ecosystem services?

2. Perceived importance and trend of services?

3. How do different watershed management scenarios affect the delivery of watershed services?

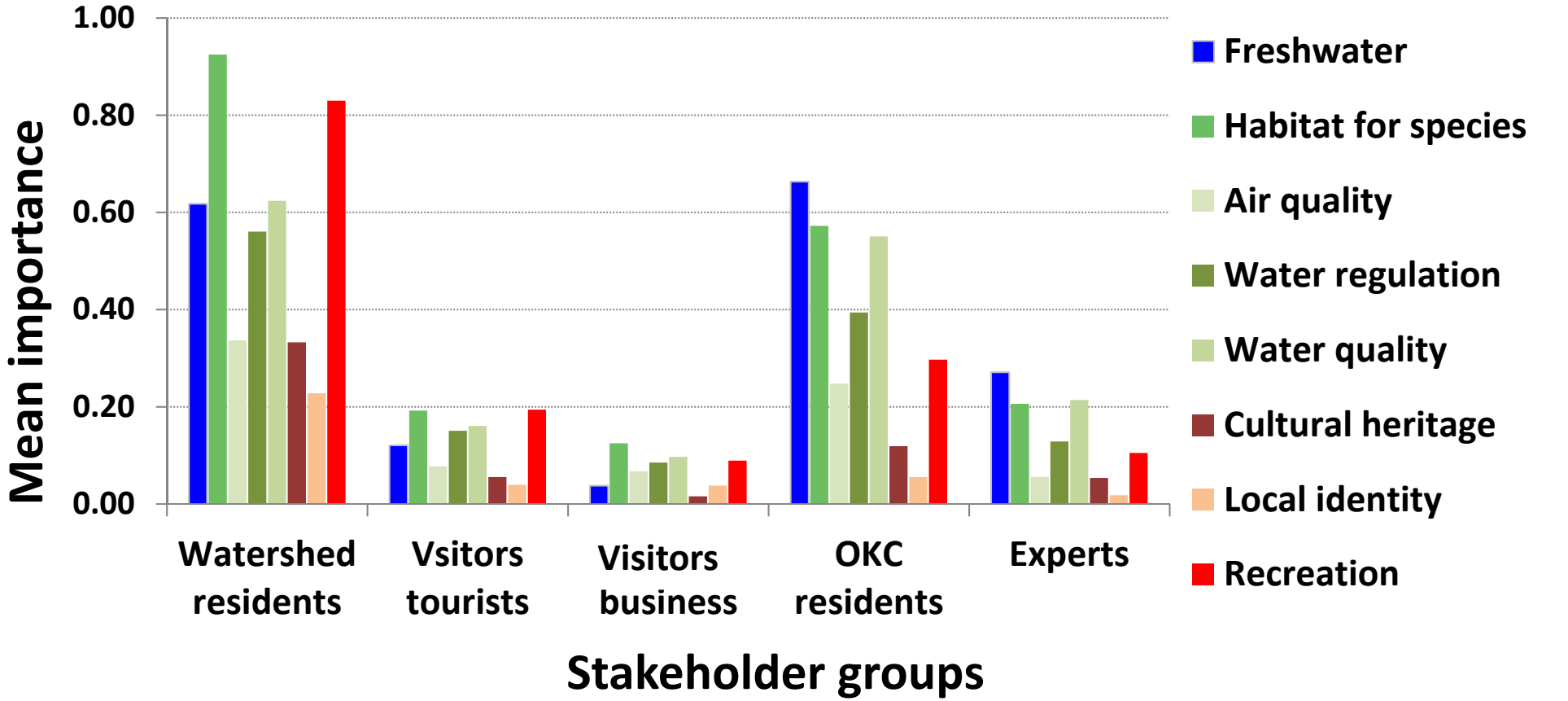
Castro et al. (2015), *JAWRA*

Which ecosystem services are considered the most important for human wellbeing?



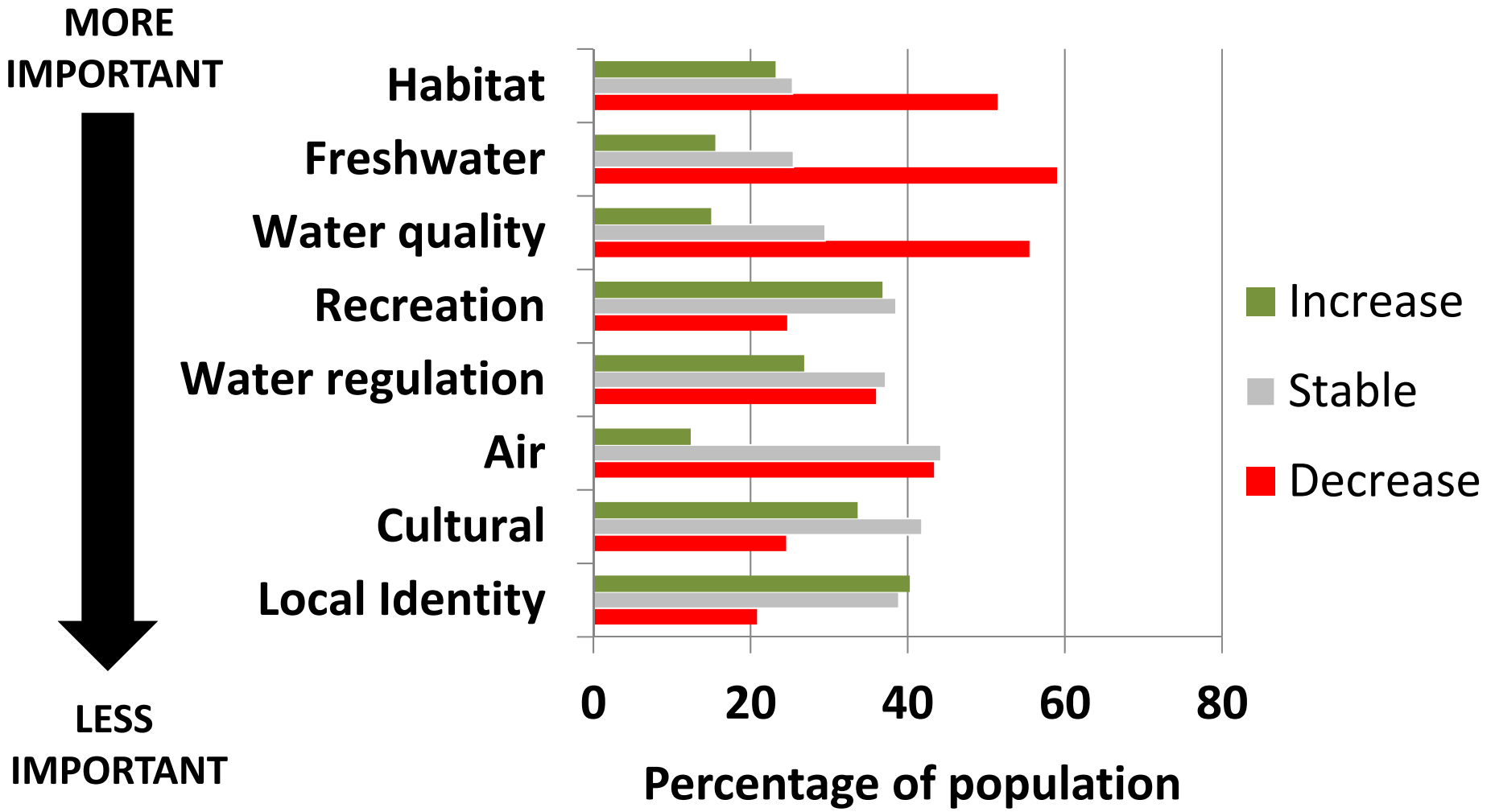
Castro et al. (2015), *JAWRA*

Stakeholder Perceptions



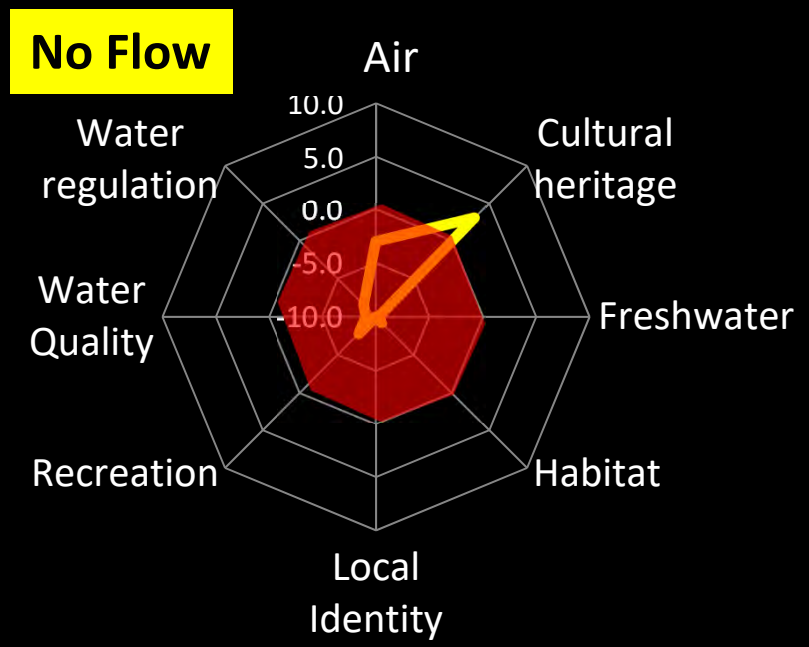
Castro et al. (2015), *JAWRA*

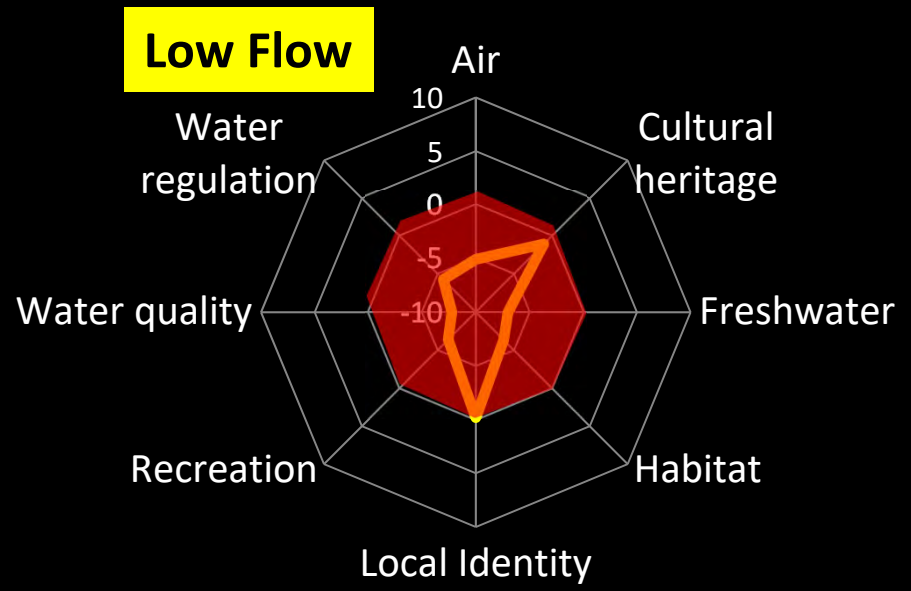
What is the perceived trend for each ecosystem service by the general public?

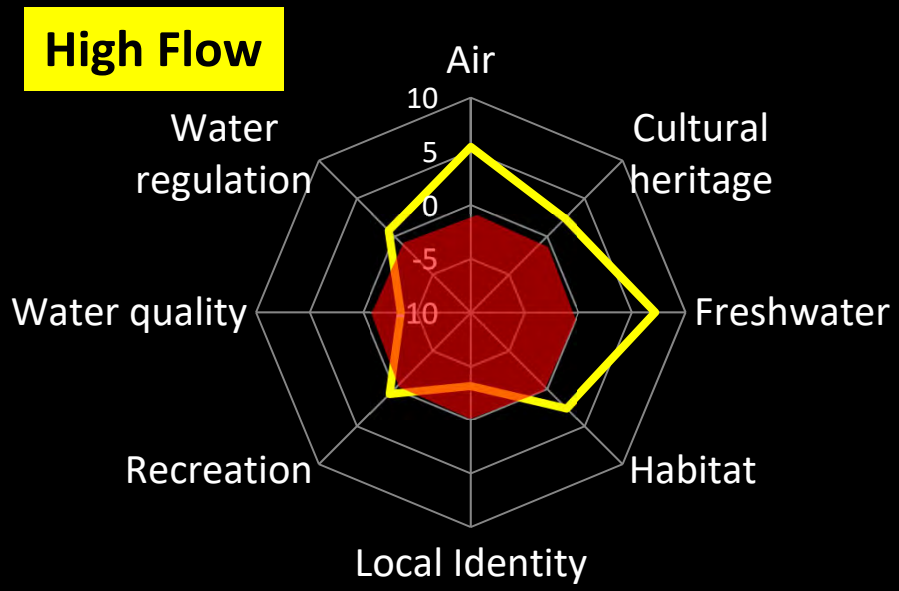


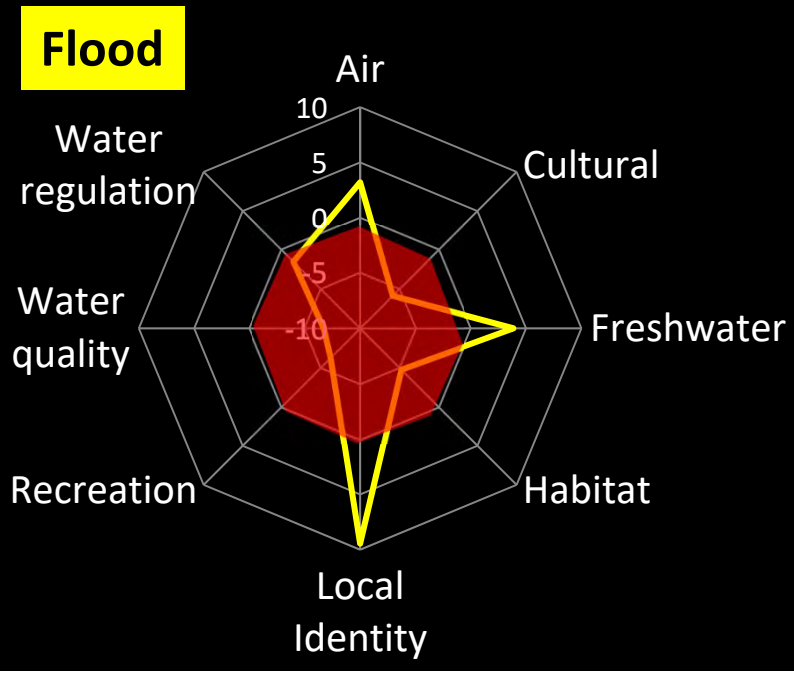
Castro et al. (2015), *JAWRA*

Effects of flow on ecosystem services?









ECONOMIC VALUE QUESTIONS

1. What is the monetary value of watershed services?

2. Which stakeholder groups are willing to pay more for watershed services?

Castro et al. (2016), *Watershed Planning & Mgt*

What explains a higher or lower WTP?

	Probit		MCOs	
Variables	Coefficient		Coefficient	
Visited before?	0.439***	(0.141)		
Government health River?	0.295 **	(0.147)	0.625**	(0.288)
Family belongs to study area?	-0.155	(0.125)	-0.344	(0.239)
Active in community affairs?	0.233**	(0.125)		
Level of education?	0.272***	(0.124)		
Age (ln)?	-0.185	(0.132)	-0.370	(0.259)
Native American Tribe?	0.267*	(0.157)	0.448*	(0.279)
Female			0.107	(0.141)
OKC residents			-0.560**	(0.187)
Income (LN)			0.403*	(0.252)
Inverse of Mill's ratio				
Log likelihood		-298.73		-713.92
Log likelihood restricted		-313.73		-1103.69
R^2				0.80
R^2 adjusted				0.79
Chi- square		29.9		
% correct predictions		64.8%		
Pseudo R^2				

Higher WTP for preserving watershed services is related to:

- Direct experiences with the river
- People who are active in their communities and who are more educated
- OKC residents are less willing to pay for preserving ES than waterhsed residents or tourists

Castro et al. (2016), *Watershed Planning & Mgt*

Economic value of ecosystem services?

Ecosystem Services	Business tourists	Visitors tourists	Watershed Residents	OKC Residents	Experts	Kruskal Wallis	Average WTP
Freshwater provision	21.1	12.44	19.5	9.26	17.52	17.2***	15.66
Water regulation	16.19	17.67	18.99	13.55	11.22	9.8**	16.3
Habitat for species	44.22	30.29	35.59	30.69	35.38	8.5*	34.08
Air Quality	30.83	5.45	7.61	8.93	5.52	10.2**	8.86
Water Quality	68.39	59.47	38.35	25.25	47.73	14.7***	39.29
Recreation	6.23	32.33	17.87	6.73	4.94	25.8***	14.08
Cultural heritage	2.29	6.23	5.17	2.01	8.9	21.7***	4.58
Local Identity	5.04	5.37	6.34	5.01	3.3	19.3***	5.47
Total WTP for ES	194.3	169.26	149.43	101.44	134.5		138.32

- WTP a total of $138 per household per year
- Water quality ($39 per household) and habitat for species ($34) were the most economically valued
- Cultural heritage ($4), local identity ($5) and air quality ($8) were the least
- Visitors ($180) and watershed residents ($150) are WTP more than OKC residents ($100)

Castro et al. (2016), *Watershed Planning & Mgt*

San Marcos River, Texas

PC: Stephen Ramirez

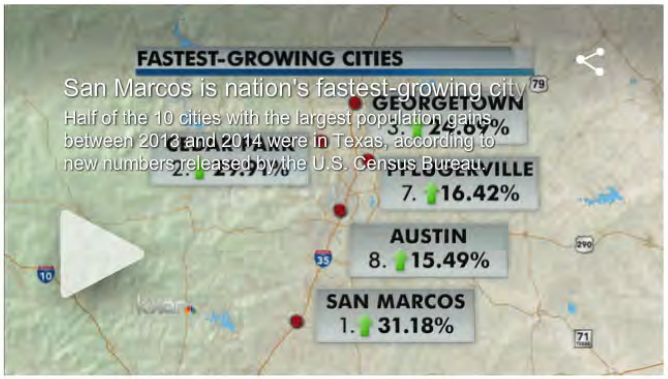
Rapidly Growing City & Region

kxan IN-DEPTH. INVESTIGATIVE.

NEWS ▾ WEATHER ▾ TRAFFIC ▾ INVESTIGATIONS REPORT IT MARKETPLACE ▾ MORE ▾

San Marcos is nation's fastest-growing city

By Eric Janzen and Sophia Beausoleil
Published: May 20, 2015, 11:20 am | Updated: May 21, 2015, 9:36 pm



Related Coverage

Austin Metro, Hays County among fastest-growing in U.S.

Hays CISD plans for expansion as population boom continues

SAN MARCOS, Texas (KXAN) — Half of the 10 cities with the largest population gains across the nation between 2013 and 2014 were in Texas, according to new numbers released by the U.S. Census Bureau. Austin, Dallas, Fort Worth, Houston and San Antonio each added more than 18,000 people during that time.

Fastest growing city in U.S. 2012 – 2014

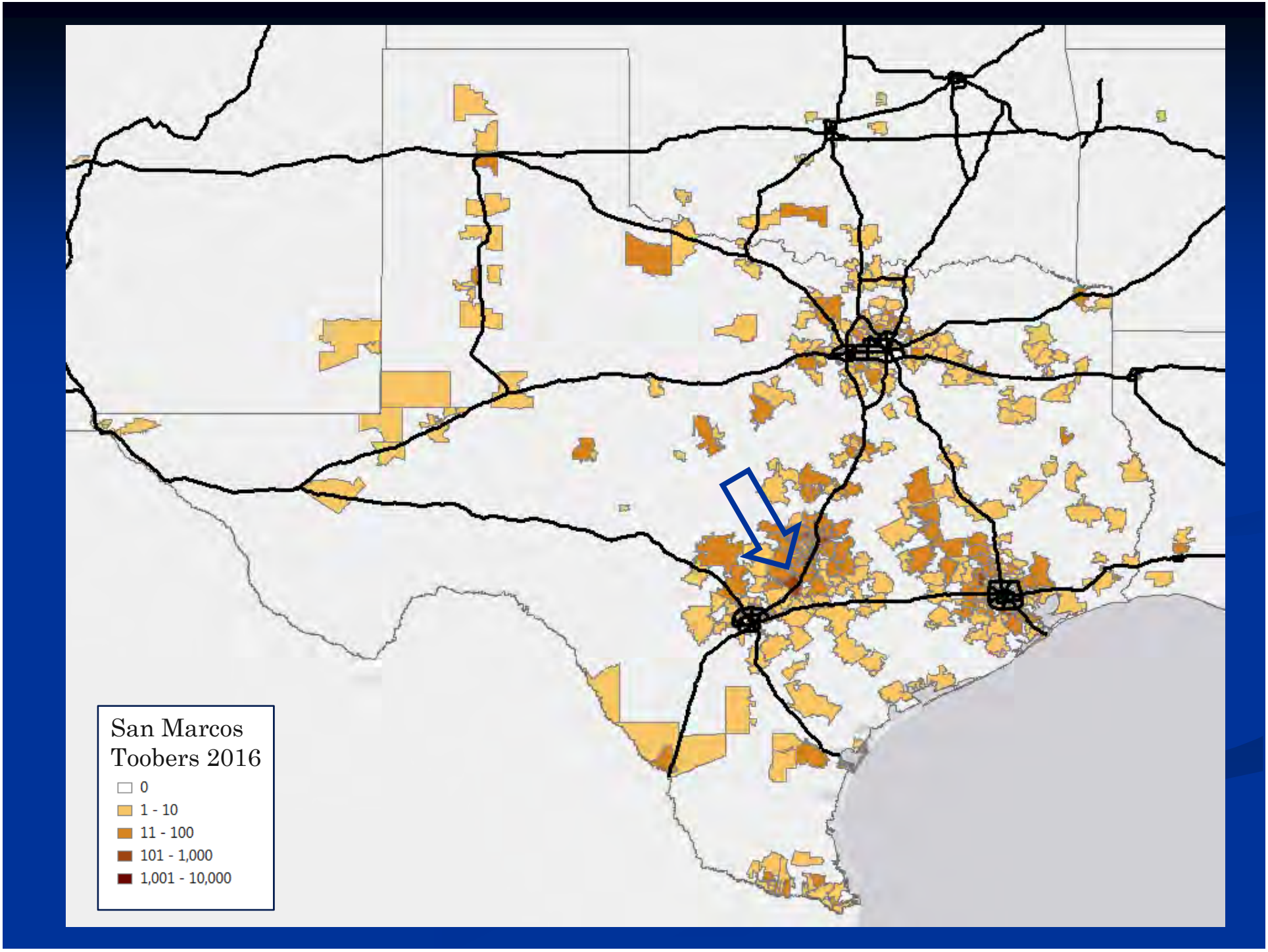
City grew ~50% from 2012 – 2017

One of fastest growing counties in nation

Located between Austin and San Antonio, two of top ten cities by population (3.5 mil)

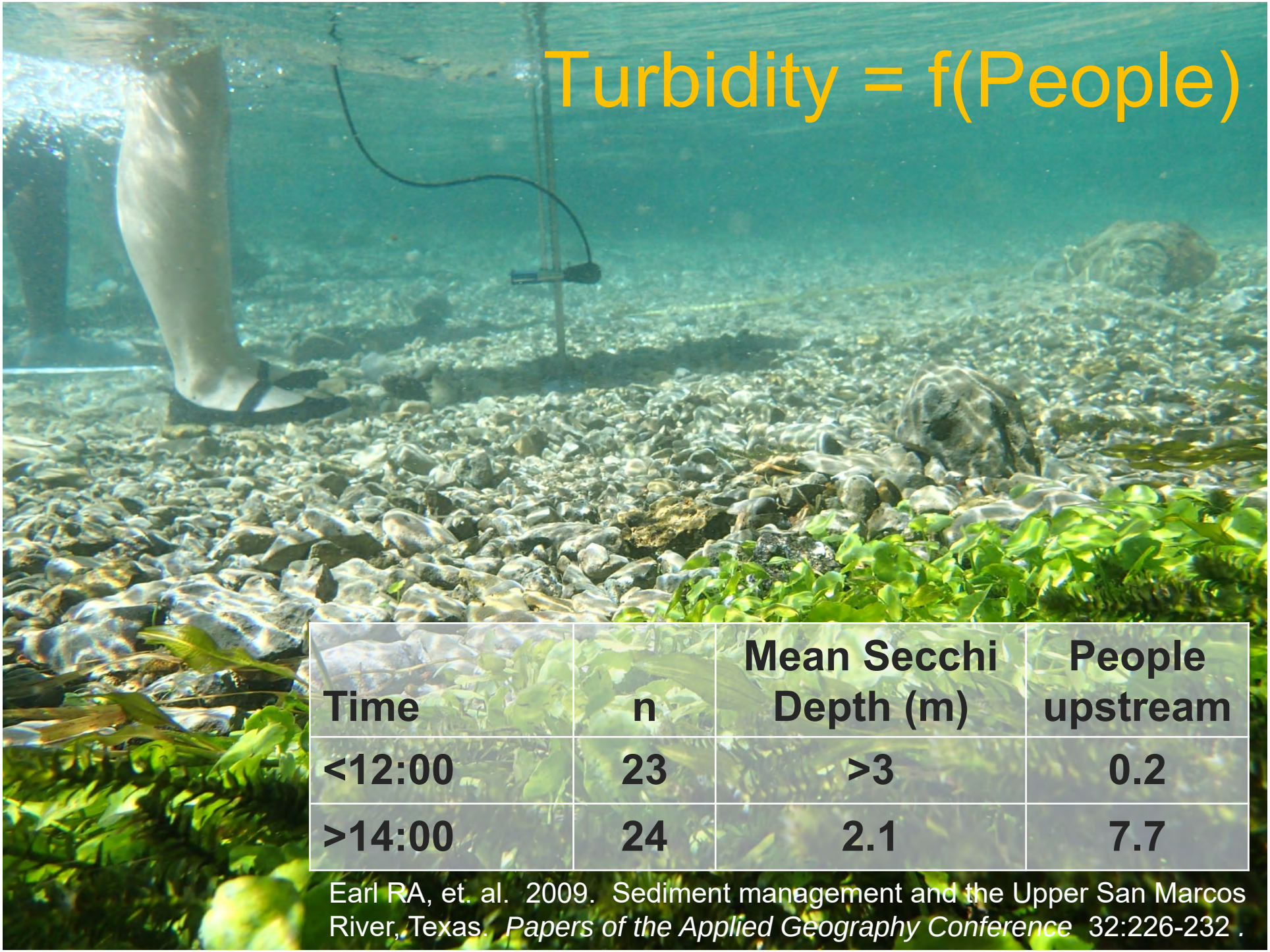
Major tourist destination (14 M/y)

San Marcos River is becoming an international tourist destination


San Marcos
Toobers 2016
0
1 - 10
11 - 100
101 - 1,000
1,001 - 10,000


Social demand is growing!

Turbidity = f(People)



Time	n	Mean Secchi Depth (m)	People upstream
<12:00	23	>3	0.2
>14:00	24	2.1	7.7

Earl RA, et. al. 2009. Sediment management and the Upper San Marcos River, Texas. *Papers of the Applied Geography Conference* 32:226-232 .

Diverse and Valuable River Ecosystem

Spring fed (200 cfs)

Flowing since memory

Exceptional water quality

Excellent habitat

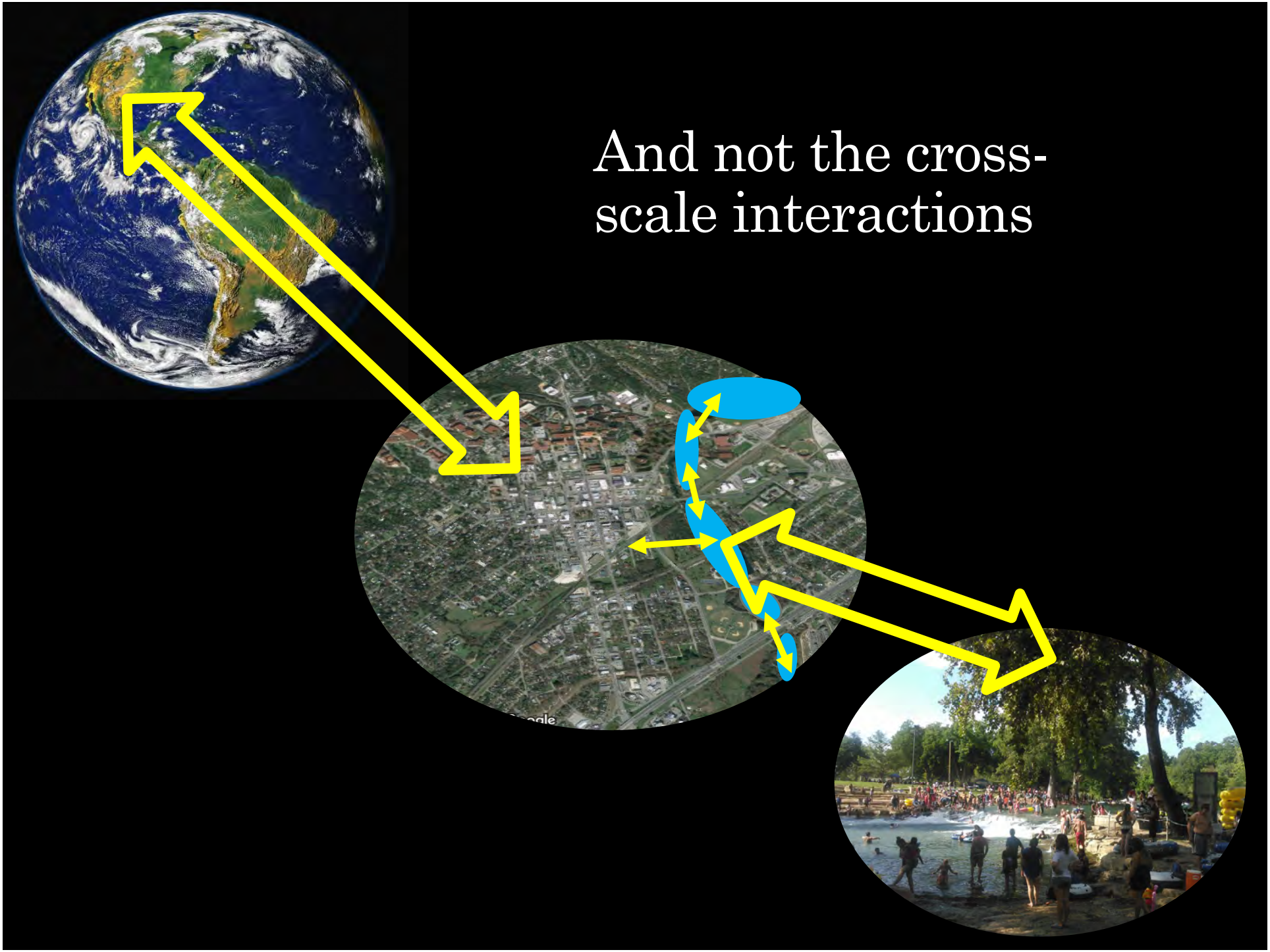
High biodiversity

7 endangered species

HABITAT CONSERVATION PLAN
EDWARDS AQUIFER

Biophysical / hydrological supply & demand are well studied…

but not the social demand


And not the cross-scale interactions

Cross-Scale Interactions (CSI)

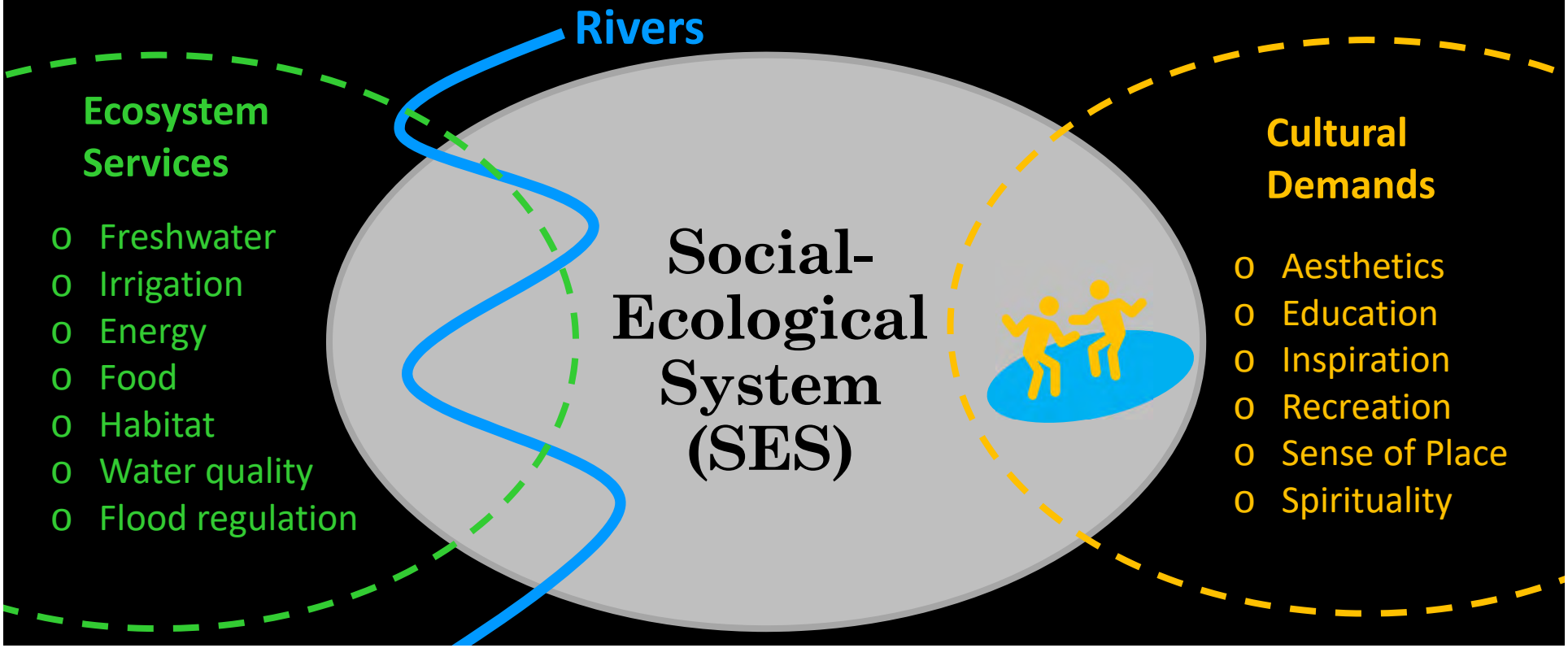
occur when processes or activities at one spatial or temporal scale interact with processes at finer or broader scales. In systems where CSI are connected, a change in an environmental driver (e.g. climate or land use) can result in process linkages and feedbacks that lead to changes in system dynamics (tipping points) or resilience.

Carpenter and Turner (2000), *Ecosystems*

Peters et al. (2007), *Ecosystems*

Julian et al. (2011), *Ecohydrology*

What are the social demands and cross-scale connections within the San Marcos River social-ecological system?



Cross-scale connections

City

Region

State

National/Global

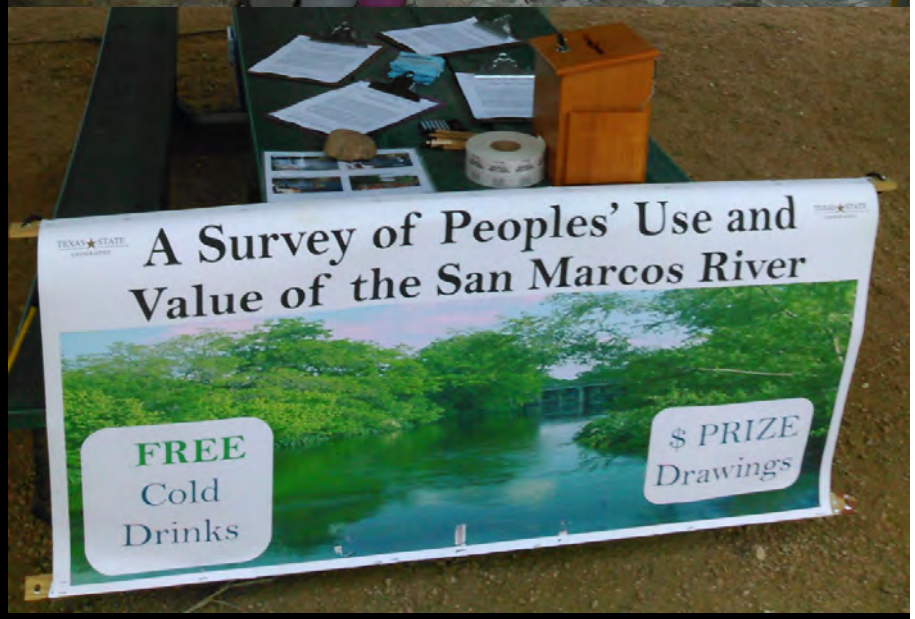
San Marcos River

Population growth/change

SanMarcos
TourSanMarcos.com

Survey Methodology

- Email, In-person, Mail-out questionnaires
- Stratified random sampling to target different sociodemographic populations
- Primarily forced, closed responses
- 49 questions total
- 20 minute average response time
- Spring & Summer of 2015
- ~3,200 complete surveys

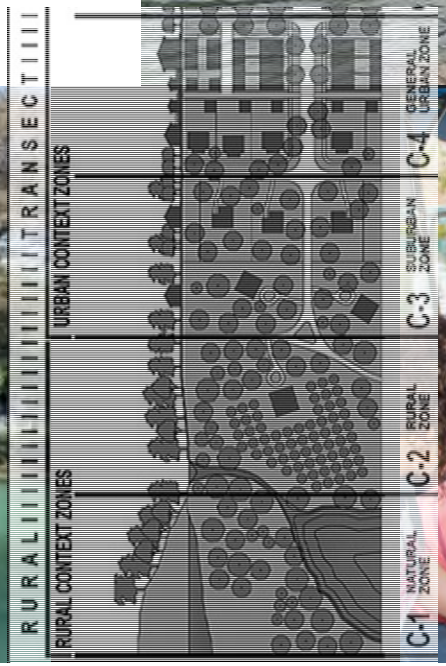


Largely based on Castro et al. (2016)

Use	Value	Perception
Visit per year, season, time of day, group size	Rank ES and CES benefits	Benefits to Human Well-Being and Fish & Wildlife
Money spent on river visits, consumables and hard goods	Money allocated for river protection and enhancement	Cleanliness of water, affect on use, preferred crowding
Sites and activities visited	Rank benefits of SMR, TXST, and Outlet Malls	Sensitivity to rapid growth, endangered species

Socio-Demographic	Life Experience
Age	Parental Education & Occupation
Gender	Youth Time Outside & Activities
Race/Ethnicity	Environment Raised In
Education	Glass Bottom Boat Tour
Income	Years Lived in SM; River proximity

TEXAS STATE UNIVERSITY
SAN MARCOS
The rising STAR of Texas

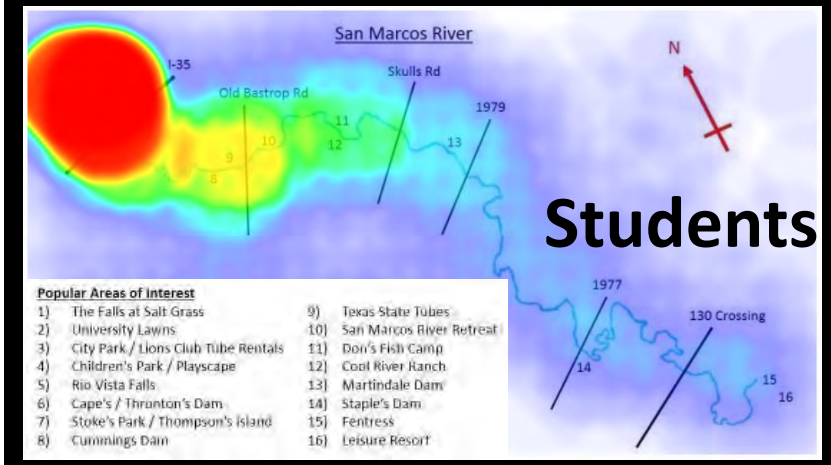


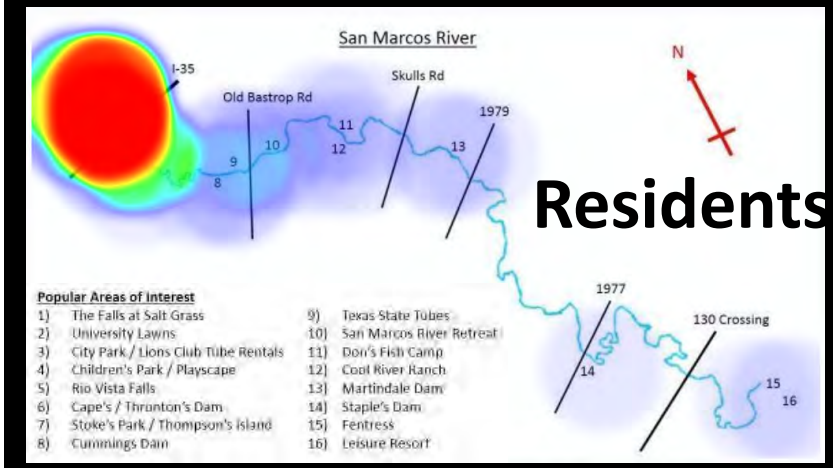
2,581 Students

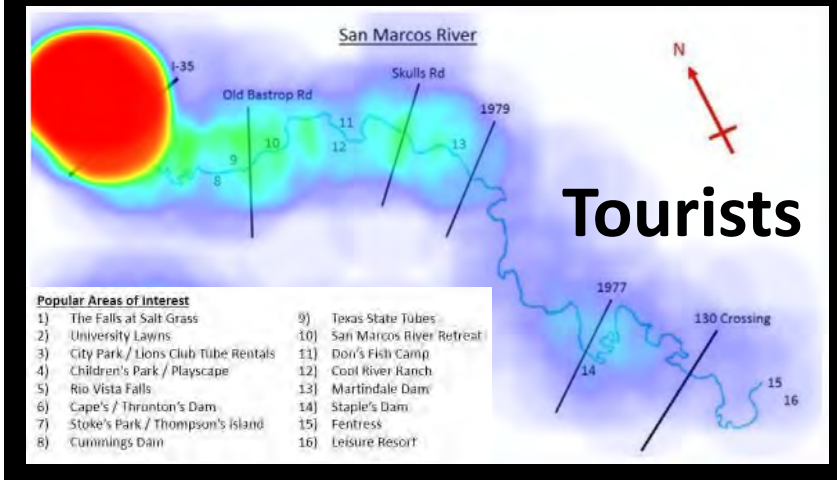
336 Residents

240 Tourists

Students	Residents	Tourists
Moderate usage	High usage, but Targeted	Seasonal usage
Value skewed towards conservation	Value heightened overall	Value changes with experience
Perception more limited	Perception more sensitive	Perception more generalized







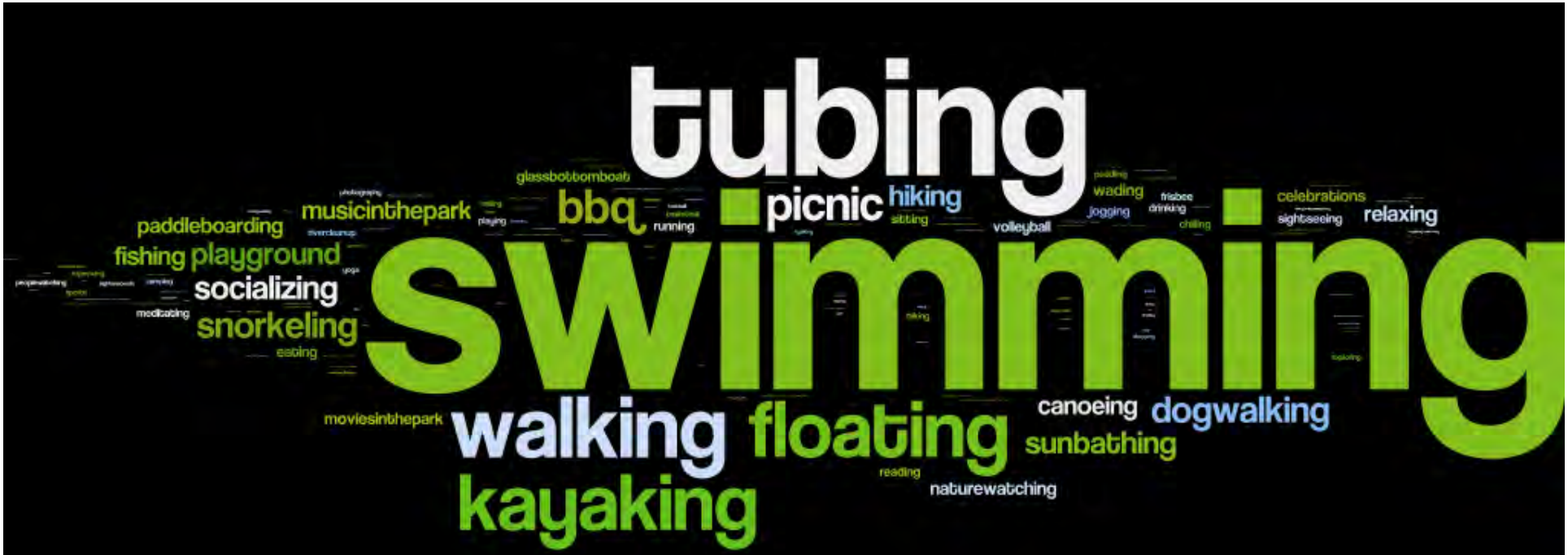
Dispersion away from the City

Ecosystem Service Importance Ranking

Ecosystem service	χ^2 statistic (df)	p-value	Post hoc summary
Water source	29.40(3)***	<0.001	**Tourists** rank slightly higher than **students** and **residents**
Food source	18.25(2)***	<0.001	**Tourists** rank slightly higher than **students** and **residents**
Water quality	17.53(2)***	<0.001	**Tourists** and **residents** rank higher than **students**
Habitat	5.22(2)^	0.074	**Students** rank slightly higher than **tourists**
Recreation	0.01(2)	0.996	No significant differences
Sense of place	74.97(2)***	<0.001	**Students** rank higher than **residents** and **tourists**; **residents** rank higher than **tourists**

Cultural Ecosystem Service Importance Ranking

Cultural ES	χ^2 statistic (df)	p-value	Post hoc summary
Sense of Place	13.50(2)**	0.001	**Tourists** (median=3) rank **significantly** lower than **students** and **residents** (median=4)
Recreation	23.44(2)***	<0.001	**Residents** (median=4) rank **significantly** lower than **students** and **tourists** (median=5)
Spirituality	7.77(2)*	0.021	**Residents** rank **slightly** higher than **students**; no other pairwise differences
Aesthetics	1.29(2)	0.542	No significant differences
Education	1.41(2)	0.494	No significant differences
Inspiration	0.12(2)	0.94	No significant differences



Social-Ecological Systems analysis

- Contact recreation most popular from group analyses
- Cultural activities ranked high for many residents
- New stakeholder groups emerged:
  - Students divided between residents and regional
  - Tourists divided between regional and non-regional

Number of annual visits to the San Marcos River

User Group	Median	Mean	SD	CV
Non-student Residents	20	57.0	83.7	1.47
Regional Students	15	32.4	49.2	1.52
Student Residents	10	29.3	50.0	1.71
Regional Tourists	10	34.4	66.1	1.92
Non-regional Tourists	2	6.1	13.9	2.28

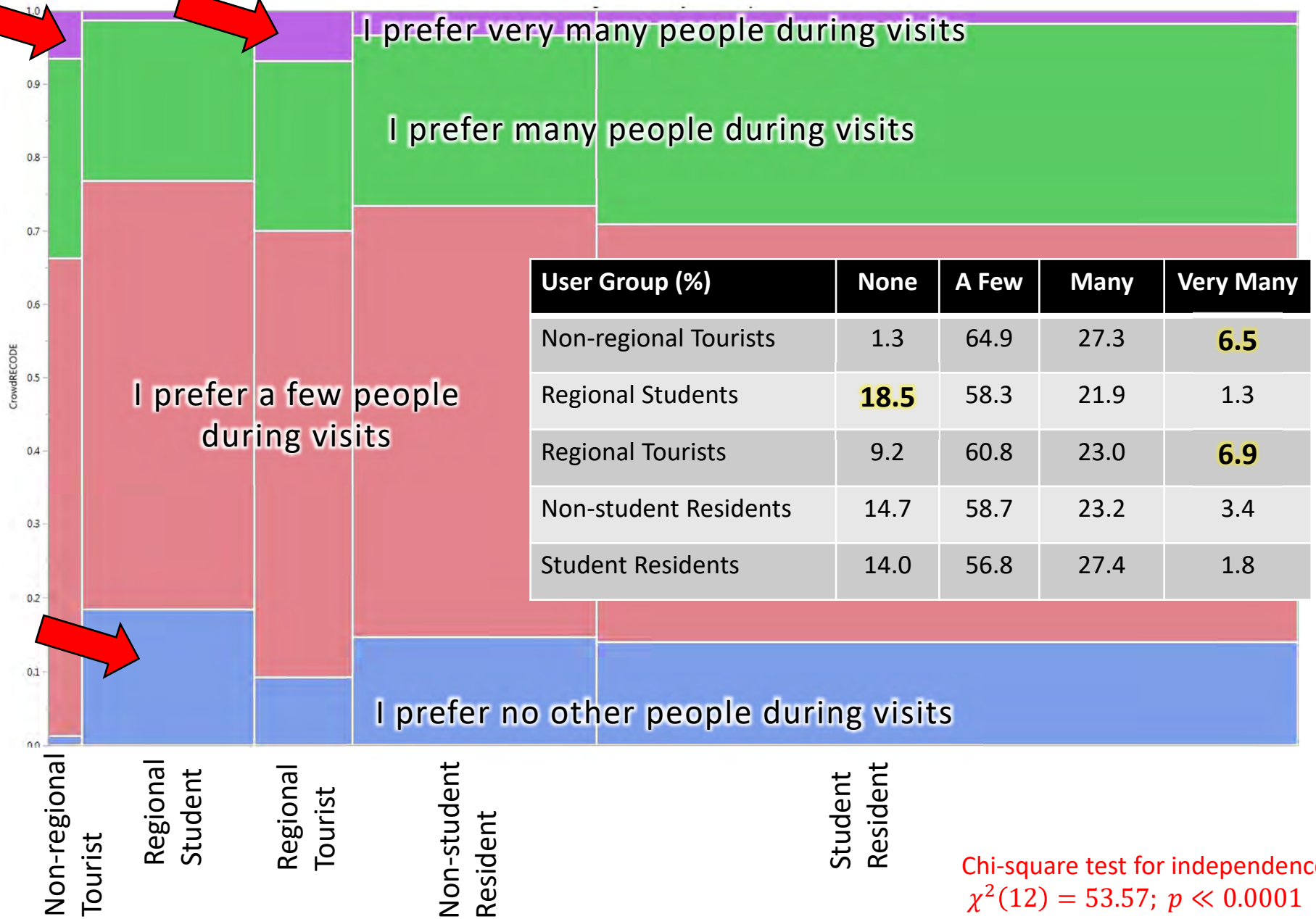
Kruskal-Wallis Test: $\chi^2(4) = 143.7;\ p \ll 0.0001$
All pairwise differences are significant at 99% confidence or better EXCEPT for:
(1) Student Residents – Regional Tourists and (2) Regional Students – Regional Tourists

How many people usually accompany you on your visits to the San Marcos River or neighboring parks?

User Group	None	One	Two or Three	Four or More	n
Non-regional Tourists	1.6%	11.5%	31.1%	**55.7%**	61
Regional Students	10.0%	20.4%	50.7%	18.9%	412
Regional Tourists	7.3%	18.4%	43.1%	**31.2%**	218
Non-student Residents	**12.6%**	**25.7%**	45.6%	16.2%	557
Student Residents	6.7%	22.2%	52.3%	18.8%	1,582

Chi-square test for independence: $\chi^2(12) = 98.35;\ p \ll 0.0001$

What is your personal preference for the amount of people in the river and parks when you visit?

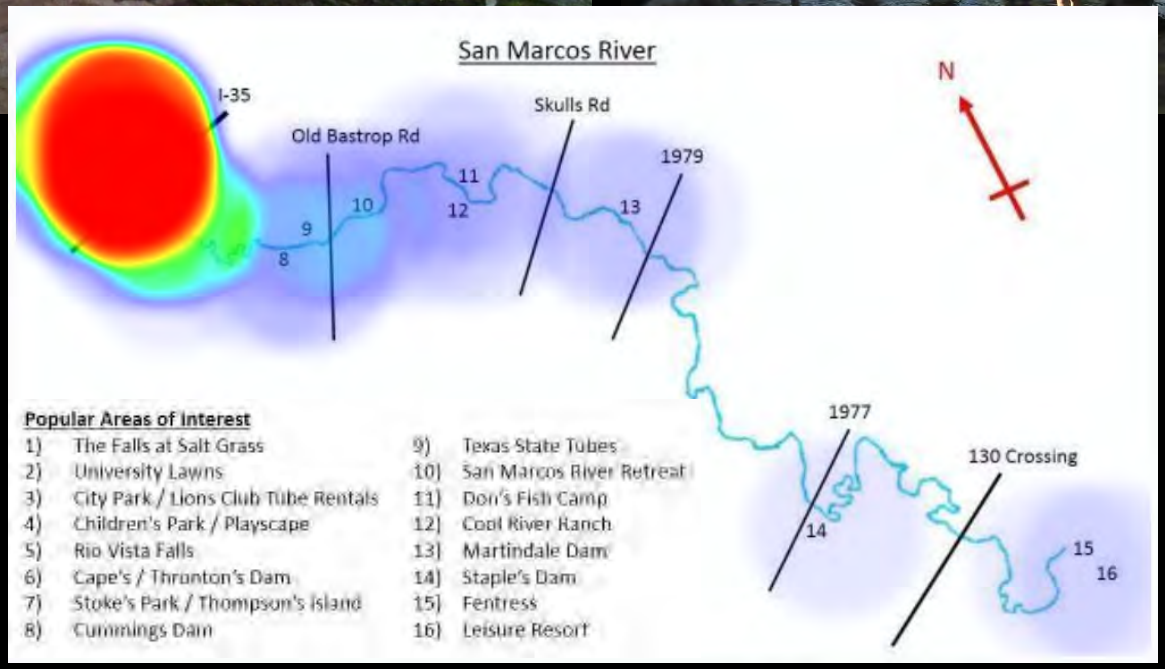


User Group (%)	None	A Few	Many	Very Many
Non-regional Tourists	1.3	64.9	27.3	**6.5**
Regional Students	**18.5**	58.3	21.9	1.3
Regional Tourists	9.2	60.8	23.0	**6.9**
Non-student Residents	14.7	58.7	23.2	3.4
Student Residents	14.0	56.8	27.4	1.8

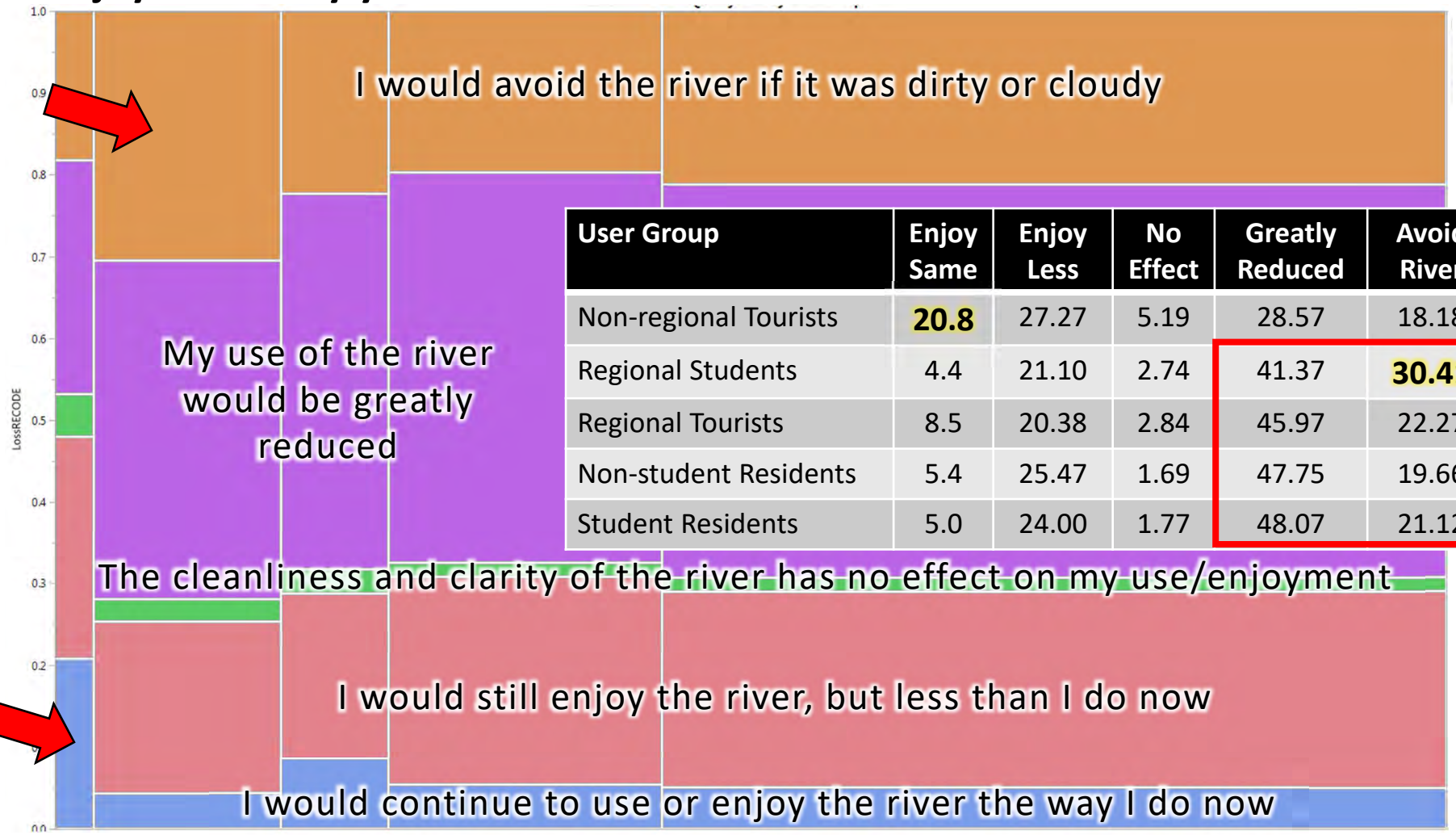
Chi-square test for independence:
$\chi^2(12) = 53.57;\ p \ll 0.0001$

How we want the river.

How we use the river.



If the San Marcos River became dirty or cloudy, would you still use and enjoy it the way you do now?

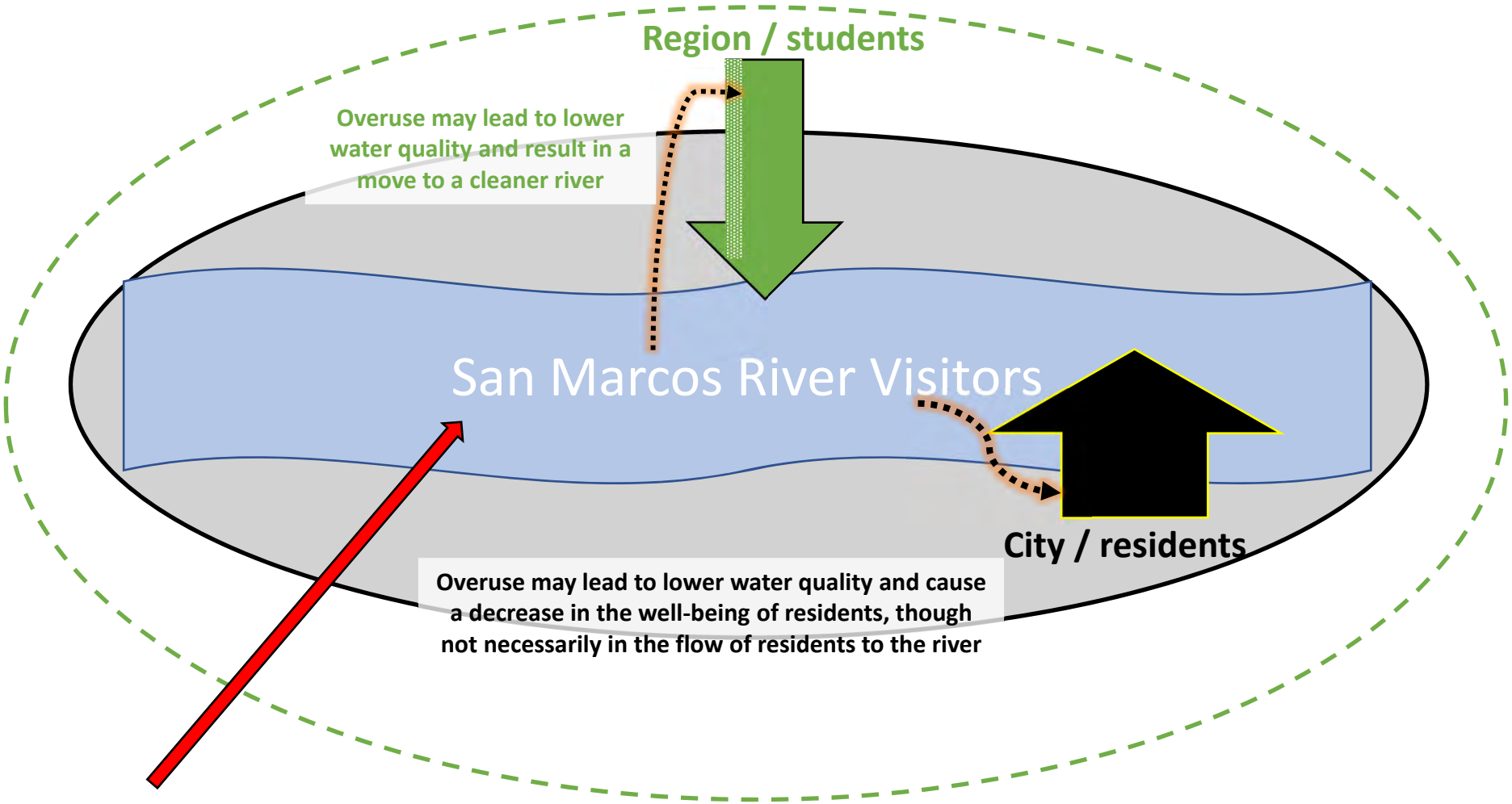


User Group	Enjoy Same	Enjoy Less	No Effect	Greatly Reduced	Avoid River
Non-regional Tourists	**20.8**	27.27	5.19	28.57	18.18
Regional Students	4.4	21.10	2.74	41.37	**30.41**
Regional Tourists	8.5	20.38	2.84	45.97	22.27
Non-student Residents	5.4	25.47	1.69	47.75	19.66
Student Residents	5.0	24.00	1.77	48.07	21.12

Chi-square test for independence:

$\chi^2(16) = 67.53;\ p \ll 0.0001$

Summary of Key Findings and Cross-scale Interactions



Non-region / tourists

Overuse may lead to lower water quality, which will not substantively affect the flow of nonregional tourists to the river

Portion of users who would avoid the river if it became dirty

They EXIST


Sirenalia Mermaid Retreat | San Marcos 2016
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