RESOURCES for the FUTURE

Quantifying the socioeconomic benefits of satellite information

NOAA Ocean Color Coordinating Group (NOCCG) Meeting

JULY 31, 2019

A brief overview of VALUABLES

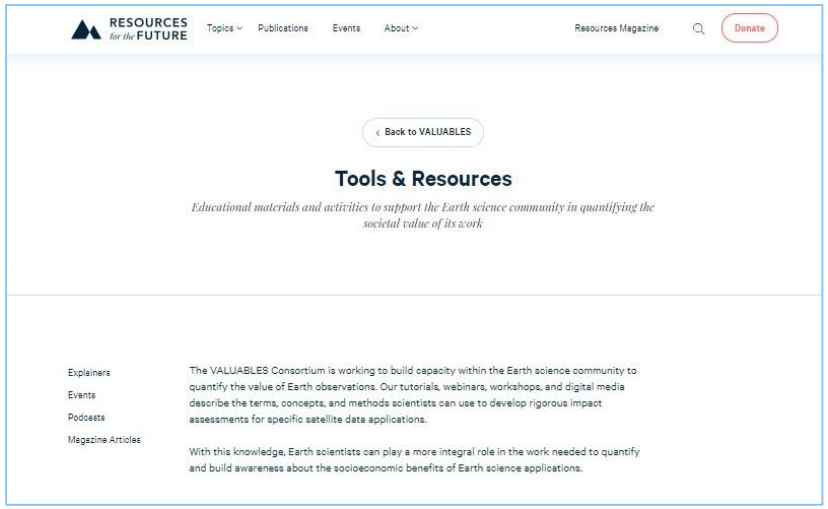
A collaboration with NASA to measure how satellite information benefits people and the environment when it is used to make decisions

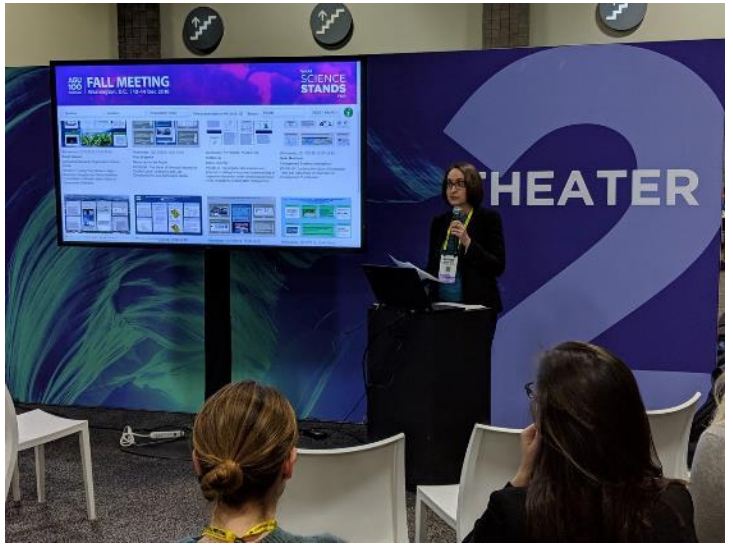
A five-year cooperative agreement between RFF and NASA

Collaborating with the Earth science community to quantify and communicate how satellite information benefits people and the environment when we use it to make decisions

VALUABLES focuses on two types of activities

1. Conducting **impact assessments**
2. Developing **educational materials** and activities to build capacity within the Earth science community to quantify the value of its work





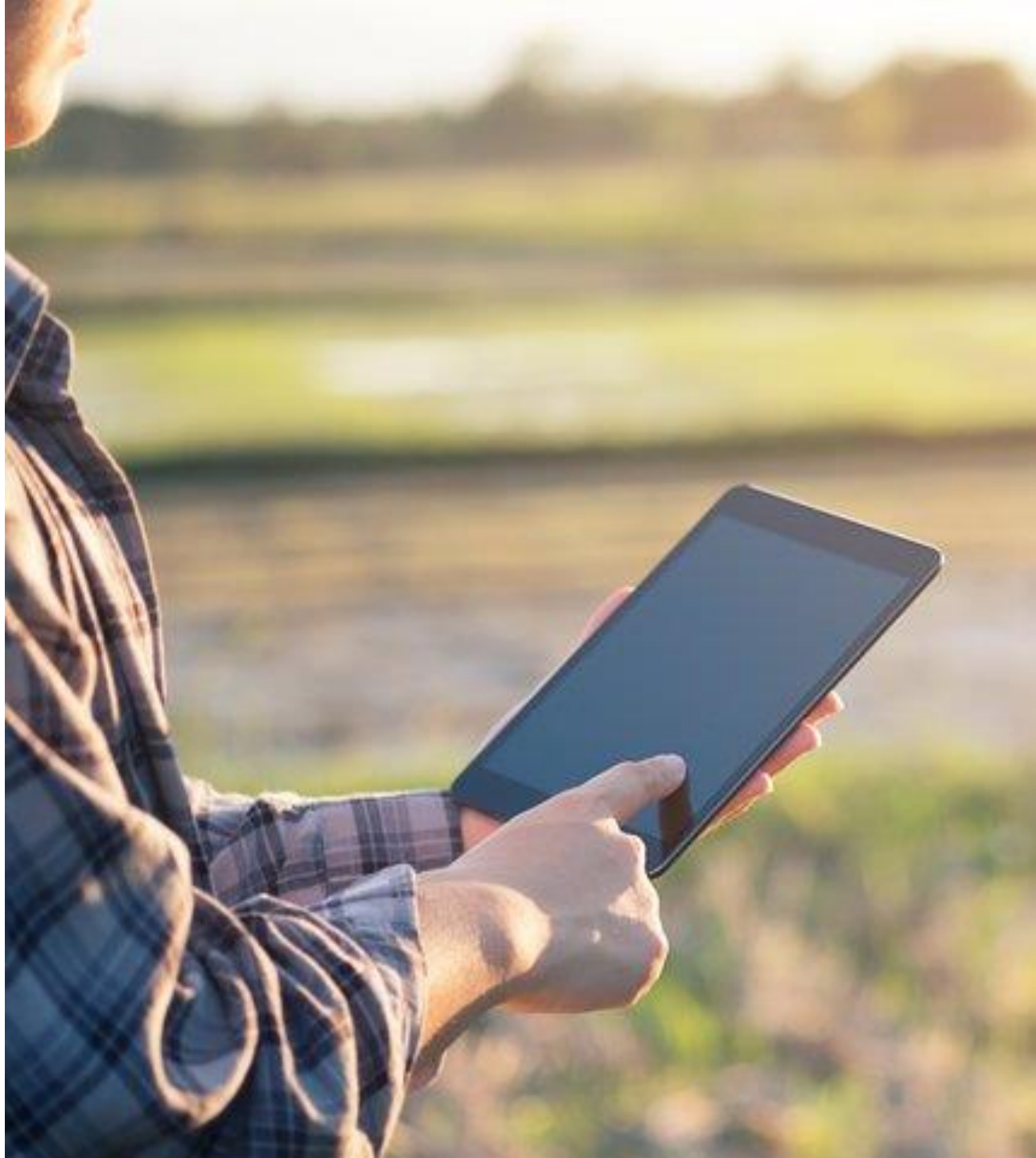
Three key principles of the value of information

What are societal benefits?

- Things that are beneficial to society:
  - Lives saved
  - Increase in firm profits
  - Increase in crop yields
  - Fishery collapses avoided
- Things that are **not** beneficial to society in and of themselves:
  - Peer-reviewed publications
  - Data downloads
  - "Improved understanding"

#1. Improved information will yield societal benefits only when it influences a decision

- Identify the decision that your improved information will inform **in the early stages of the project**
- **Be specific** about the decision that will be informed.
  - "An improved forecast of *x* can help inform water management" is too vague.
  - "An improved forecast of *x* will help operators of Shasta Dam optimize the timing of releases to maintain cold water pools below the dam that are essential for salmon habitat" is better.



#2. The societal benefits of improved inforamtion depend on the decision context

- The societal benefits of improved information will be large when:
  - The improved information yields a large reduction in uncertainty
  - There is a lot at stake in the decision context
    - There are very good and very bad states of the world
    - Available decisionmaker actions can change outcomes

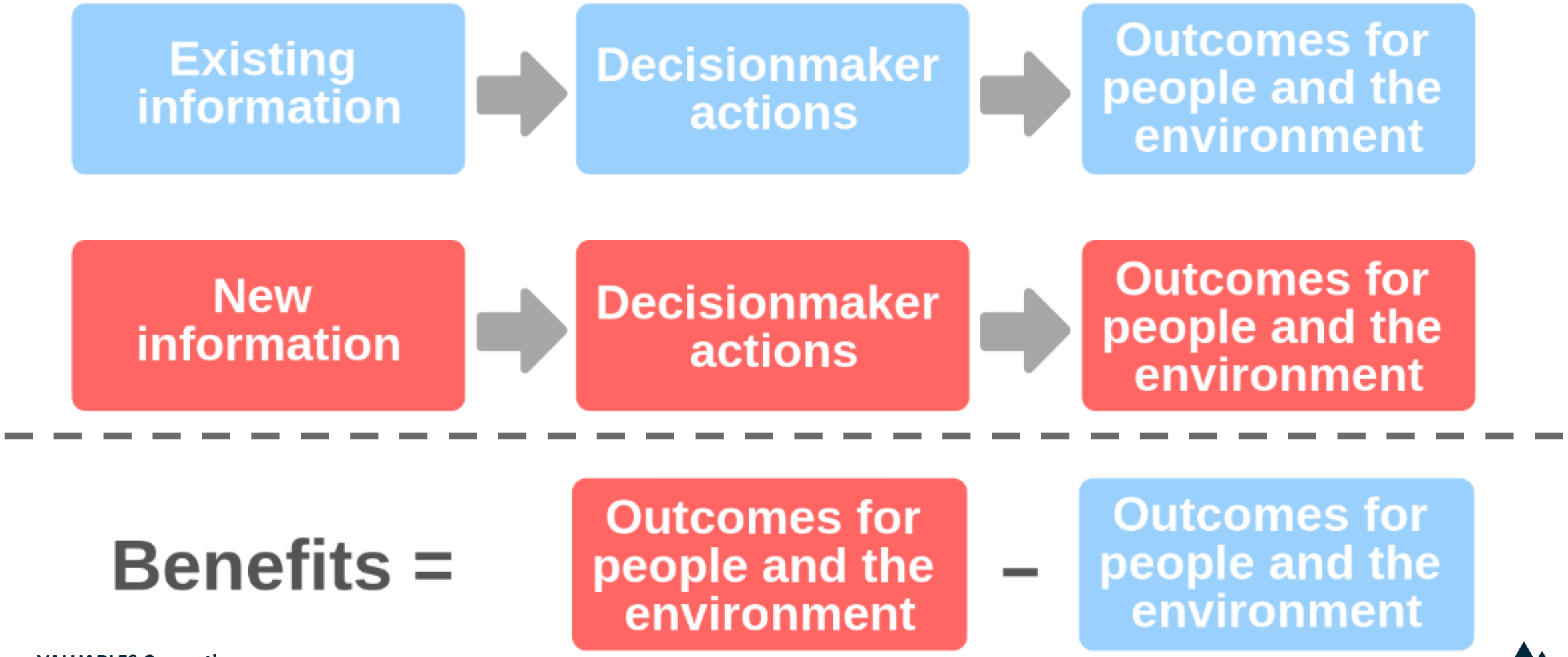
#3. Design a strategy to measure the societal benefits of your improved information (even if you don't actually plan to do it)

1. Map the causal logic of how your improved information will produce societal benefits
2. Choose metrics to measure the relevant societal benefit
3. Design an empirical strategy to identify whether the societal benefit is realized as a result of the information being available

Impact assessments

Measuring the socioeconomic benefits that Earth observations provide when people use them to make decisions

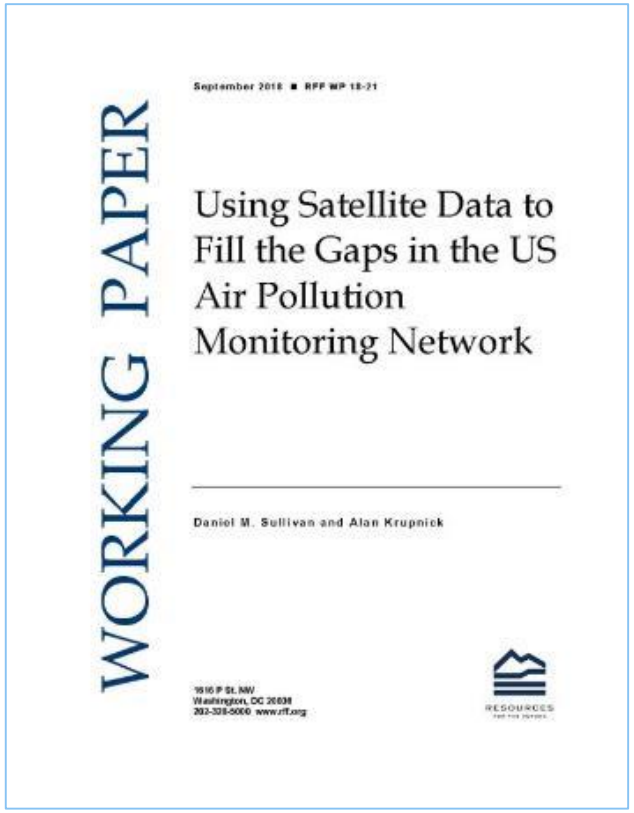
The “theory of change”



VALUABLES IA: Air quality

What would be the value of using satellite data to enforce the Clean Air Act's National Ambient Air Quality Standards?

- **Existing information:** Ground-based air pollution monitors
- **New information:** Satellite data (AOD from MODIS MISR (Terra) and SeaWIFS (OrbView-2))
- **Estimated benefit:** 5,452 premature deaths could have been avoided in 2016 and 2017, a gain to society of $49 billion



(Sullivan and Krupnick, 2018)

VALUABLES IA: Wildfire

What were the costs savings from using Landsat imagery to prioritize post-wildfire response activities for the 2013 Elk Complex wildfire?

- **Existing information:** Helicopters
- **New information:** Helicopters and Landsat imagery
- **Estimated benefit**
  - **Per incident:** A savings of between $14,948 and $15,063 when Landsat imagery is used
  - **Over 5 years:** A savings of between $7.48 million and $7.97 million

(Bernknopf et al., in preparation)

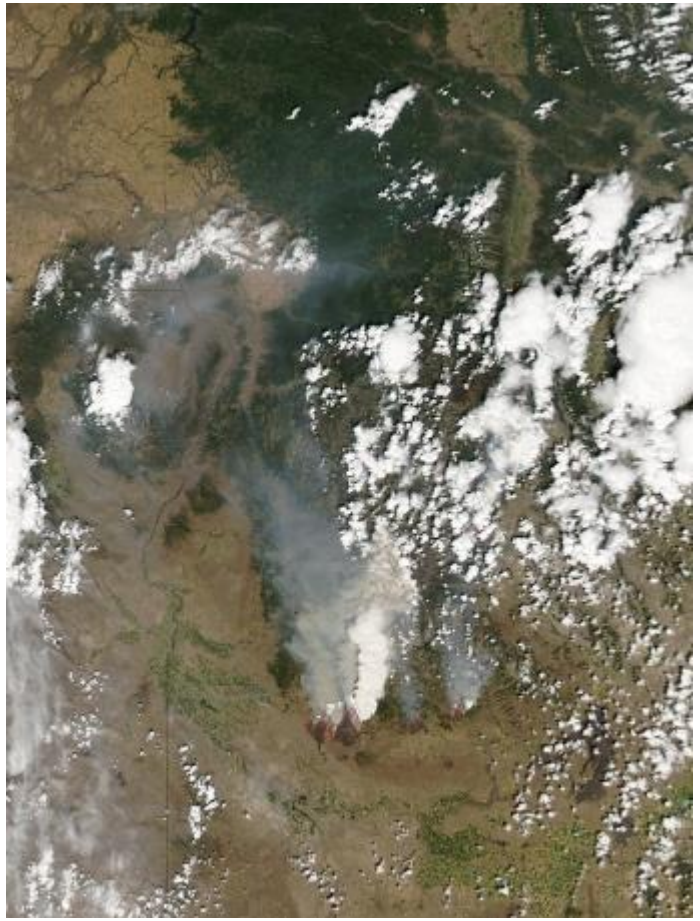


Image courtesy Jeff Schmaltz, LANCE/EOSDIS MODIS Rapid Response Team at NASA GSFC. Central Idaho, August 10, 2013

The RFF/CyAN study

Quantifying the Socioeconomic Benefits of Using Satellite Information to Detect Harmful Algal Blooms and Manage Recreational Advisories in U.S. Lakes

Study outline

A. Introduction
B. Background on Harmful Algal Blooms
C. Remote sensing of freshwater HABs
D. Guidance protocols and how information informs decision context
    A. Utah/Utah Lake
    B. Ohio/Lake Erie
E. Outcomes
    A. Health
    B. Recreation
F. Event Study: Utah Lake in 2017

Event study background

- Stroming, Kuwayama, Mabee, and Schaeffer (in preparation)

The Salt Lake Tribune

Toxic algae's return to Utah Lake could force it to close for holiday weekend

Water samples collected over past two weeks show the germs spreading fast in the lake, and hot weather is making it worse.

Ben Holcomb, who specializes in harmful algal blooms at the Utah Department of

As long as the warning is in place, Holcomb said, those who visit Provo Bay this weekend should avoid full immersion in the water to prevent exposure to the algae's toxins. Ingesting microcystin can cause nausea, abdominal pain, diarrhea and vomiting. Contact can cause eye irritation and rash.

Theory of change for event study

Empirical strategy

1. *Determine how much earlier decisionmakers were able to take action thanks to satellite data.*
   Managers were able to close the lake one month earlier (based on interviews).
2. *Estimate the number of individuals who visit the Lake in a typical season and engage in activities that would expose them to a HAB.*
   Lake visitation during July 2015 ≈ 20,000. Percent of visitors who engage in boating or swimming = 39.3% (based on Utah State Parks data).
3. *Estimate the reduction in visitors engaging in these activities that would result from decisionmaker actions (e.g., issuing advisories, closing the lake).*
   Assume that closure reduced the number of visitors to 0 → 7,860 fewer people were exposed to HAB.
4. *Estimate the reduction in human health impacts (e.g., number of gastrointestinal illnesses avoided) that can be attributed to the reduction in human exposure to the HAB.*
   5% of exposed individuals experience gastrointestinal symptoms (Stewart et al. 2006; CDC 2014) → ~ 400 fewer cases
5. *Estimate the societal benefit of reduced human health impacts (e.g., through avoided hospitalization costs or willingness to pay to avoid the health impacts).*
   Societal cost per case of gastrointestinal illness is $1,500 (Henson et al. 2008) → Total societal cost avoided ≈ $600,000

1. Determine how much earlier decisionmakers were able to take action thanks to satellite data

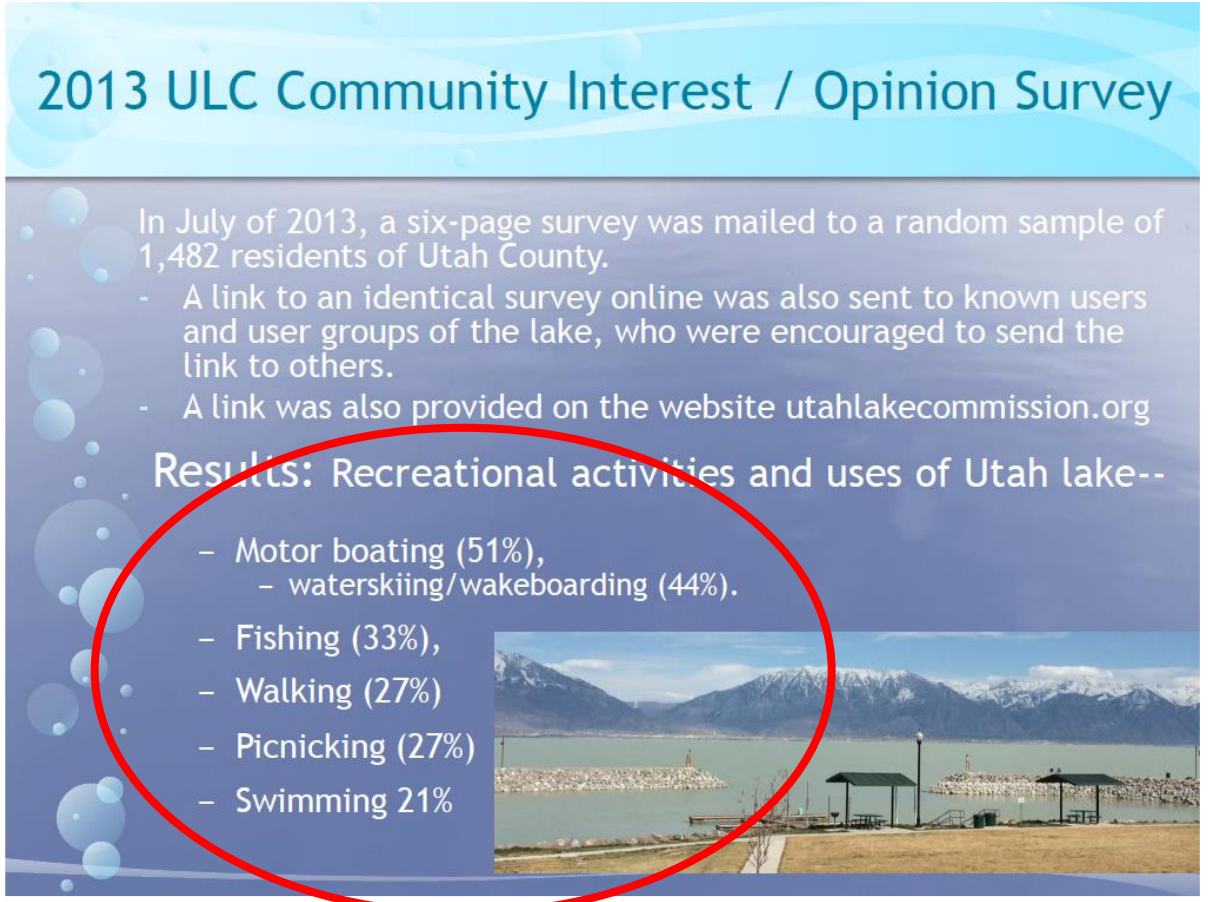
- In-situ sampling takes place once a month
- CyAN warning delivered soon after in-situ sampling found no indications of HAB
- Assume that CyAN provided one month lead time

2. Estimate the number of individuals who visit the Lake in a typical season…

Utah Lake State Park - Visitation Data

	January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
2018	10	51	-	68	9,285	31,984							41,397
2017	641	3,607	3,514	7,888	24,044	52,068	22,498	13,468	10,906	3,259	1,760	150	143,802
2016	1,269	2,052	2,642	11,812	13,869	42,637	21,668	9,486	6,172	3,447	1,650	325	117,029
2015	503	3,255	2,149	14,156	18,800	43,010	27,426	18,484	6,108	5,341	641	673	140,546
2014	653	1,226	3,221	8,638	29,270	39,346	32,839	19,609	10,153	4,679	553	712	150,899
2013	6,992	11,198	17,933	25,715	47,823	57,204	29,272	19,218	14,211	2,929	742	675	233,912
2012	6,623	9,700	19,861	30,789	50,073	38,832	42,065	42,358	19,138	8,830	7,094	5,059	280,422
2011	6,871	11,442	17,250	27,821	37,935	45,540	53,866	49,490	13,495	9,616	5,802	6,231	285,359
2010	5,265	9,273	17,846	26,202	30,366	45,387	61,067	36,722	24,073	10,170	6,406	5,887	278,664
2009	5,058	10,454	22,177	23,050	41,712	86,232	63,518	39,903	24,165	8,128	9,622	2,933	336,952
2008	7,793	7,007	18,122	36,949	30,087	43,551	58,291	49,330	9,993	11,984	5,277	6,356	284,740
2007	4,476	12,107	16,187	29,196	48,612	23,631	57,922	39,466	17,885	9,018	6,831	5,505	270,836
2006	5,996	10,078	15,895	25,970	42,465	41,541	54,945	37,285	8,608	11,570	5,187	5,731	265,271
2005	8,991	12,641	16,537	25,155	37,761	40,683	53,645	25,382	13,743	6,878	4,811	6,338	252,565
2004	229	535	2,421	5,173	42,592	43,842	38,192	10,000	3,021	8,580	6,633	4,993	166,211
2003	9,385	3,189	5,880	4,625	11,939	17,219	16,809	7,150	3,298	2,776	533	273	83,076

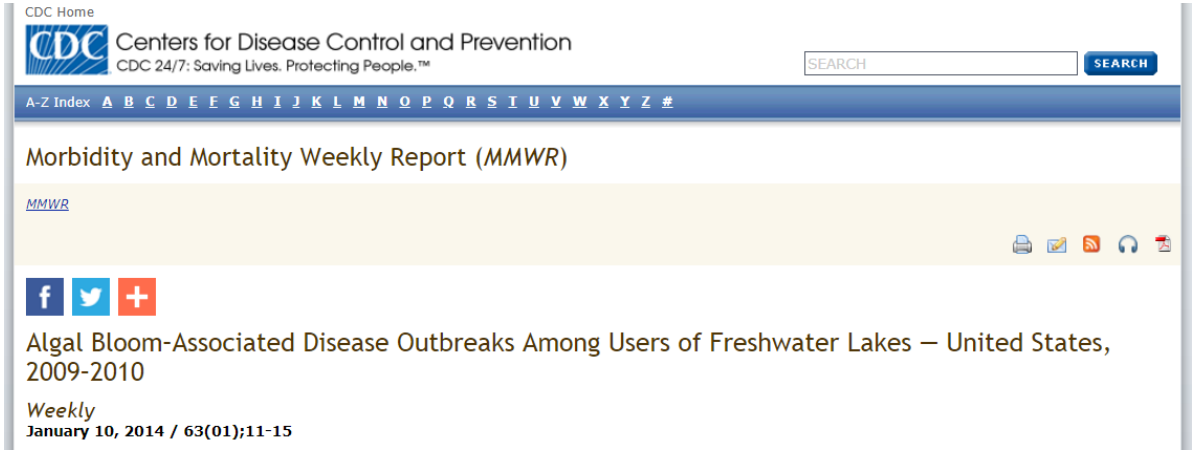
…and engage in activities that would expose them to a HAB



3. Estimate the reduction in visitors engaging in these activities that would result from decisionmaker actions

- Assume that closure reduced the number of visitors to 0

4. Estimate the reduction in human health impacts that can be attributed to the reduction in human exposure to the HAB



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SEARCH

A-Z Index A B C D E F G H I J K L M N O P Q R S T U V W X Y Z #

Morbidity and Mortality Weekly Report (*MMWR*)

MMWR

Algal Bloom-Associated Disease Outbreaks Among Users of Freshwater Lakes — United States, 2009-2010

Weekly
January 10, 2014 / 63(01);11-15

TABLE 2. Reported exposure, health effects, and health-care use resulting from harmful algal bloom–associated waterborne disease outbreaks — United States, 2009–2010

Outbreak (by state)	Cases	Health-care use*			Reported exposure†	Reported health effects (no.)§					
		Health-care provider	Emergency department	Hospitalized		Gastrointestinal	General	Dermatologic	Eye/Ear	Neurologic	Respiratory
New York (Outbreak 1)	2	1	0	0	Contact			Rash (2), swelling (1), sores (1)			
New York (Outbreak 2)	2¶	0	0	0	Contact				Watery eyes (2)		Nasal congestion (2)
New York (Outbreak 3)	2	0	0	0	Contact			Rash (2)			
Ohio (Outbreak 4)	3	1	0	0	Contact, ingestion, inhalation	Abdominal cramps (1), diarrhea (1), anorexia (1)	Dizziness (1), headache (1), muscle aches (1), fatigue (1), sore throat (2)	Rash (1), skin irritation (1)		Neurologic symptoms (1)	Cough (1), congestion (1), wheezing (1), shortness of breath (1)
Ohio (Outbreak 5)	19	19	0	0	Contact, ingestion, inhalation	Vomiting (11), nausea (11), abdominal cramps (7), diarrhea (5)	Fever (2)	Rash (6)	Eye irritation (5), earache (5)		
Ohio** (Outbreak 6)	7††	2	0	0	Contact, ingestion, inhalation	Anorexia (2), diarrhea (1), nausea (1)	Fever (2), fatigue (2), headache (1), muscle/joint pain (1), malaise (1), weakness (1), sore throat (1)	Rash (6), skin irritation (1)	Visual disturbance (1), earache (1)	Confusion (1)	Cough (1), wheezing (1)
Ohio (Outbreak 7)	9	3	2	0	Contact	Abdominal cramps (3), diarrhea (3), nausea (3), vomiting (2)	Fever (2), headache (2)	Rash (8)	Eye irritation (1), earache (1)	Neurologic symptoms (2), tingling (2), confusion (1)	Respiratory symptoms (1)
Ohio§§ (Outbreak 8)	8	5	5	1	Contact, ingestion, inhalation	Nausea (5), vomiting (4), diarrhea (4), abdominal cramps (2), anorexia (1)	Fever (4), headache (4), dizziness (1), fatigue (3), malaise (1), back pain (1)	Skin irritation (6), rash (3)	Earache (2)	Confusion (3), neurologic symptoms (3)	Respiratory symptoms (5), cough (2), wheezing (1), chest tightness (1)
Ohio (Outbreak 9)	2	0	0	0	Contact, ingestion	Diarrhea (2), vomiting (2)					
Washington (Outbreak 10)	3	2	0	0	Unknown	Gastroenteritis (3)	Fever (1)				
Washington (Outbreak 11)	4	1	0	1	Ingestion	Gastroenteritis (3)		Dermatologic symptoms (1)	Ear symptoms (1)		Respiratory symptoms (1)

* Multiple levels of health care might have been accessed by a person (e.g., used emergency department and was hospitalized). No deaths were reported.

4. Estimate the reduction in human health impacts that can be attributed to the reduction in human exposure to the HAB

BMC Public Health

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Abstract
Background
Methods
Data analysis
Results and discussion
Conclusion
Declarations

Research article | Open Access | Open Peer Review

Epidemiology of recreational exposure to freshwater cyanobacteria – an international prospective cohort study

Ian Stewart, Penelope M Webb, Philip J Schluter, Lora E Fleming, John W Burns Jr, Miroslav Gantar, Lorraine C Backer and Glen R Shaw

Table 3
Frequency (percentage) of subjects reporting symptoms against level of cyanocyanobacteria exposure: low (cell surface area <2.4 mm^2/mL), intermediate (2.4 – 12.0 m 12.0 mm^2/mL) and high (>12.0 mm^2/mL).

Symptoms		Cyanobacteria exposure			
		Low *n*(%)	Intermediate *n* (%)	High *n* (%)	p-value
Gastro-intestinal symptoms					0.89
	None	871 (94)	199 (95)	158 (95)	
	Mild	30 (3)	5 (2)	5 (3)	
	Moderate/severe	27 (3)	5 (2)	3 (2)	

5. Estimate the societal benefit of reduced human health impacts

International Journal of Food Microbiology
Volume 127, Issues 1–2, 30 September 2008, Pages 43-52

Estimation of the costs of acute gastrointestinal illness in British Columbia, Canada

S.J. Henson [a], S.E. Majowicz [b, c], O. Masakure [a], P.N. Sockett [b, c], L. MacDougall [d], V.L. Edge [b], M.K. Thomas [b], M. Fyfe [d], S.J. Kovacs [b], A.Q. Jones [c, e]

Abstract

The costs associated with gastrointestinal infection (GI) in the province of British Columbia, Canada, were estimated using data from a population-based survey in three health service delivery areas, namely Vancouver, East Kootenay and Northern Interior. The number of cases of disease, consequent expenditure of resources and associated economic costs were modeled as probability distributions in a stochastic model. Using 2004 prices, the estimated mean annual cost per capita of gastrointestinal infection was CAN$128.61 (€207.96), with a mean annual cost per case of CAN$1,342.57 (€2,170.99). The mean estimate of the overall economic burden to British Columbia was CAN$514.2 million (€831.5 million) (95% CFI CAN$161.0 million to CAN$5.8 billion; €260.3 million to €9.38 billion). The major element of this cost was the loss of productivity associated with time away from paid employment by both the sick and their caregivers. Sensitivity analysis suggested that the uncertainty associated with the base model assumptions did not significantly affect the estimates. The results are comparable to those obtained in an earlier study using a similar analytical framework and data from the city of Hamilton, Ontario, Canada.

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