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Social Observation for Sustainability Science about Water

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Abstract: I advance the following argument: (1) Coupled observation of humans and nature at large scale is important to many fundamental questions of sustainability. (2) Current programs observing natural and social systems are inadequate to address fundamental questions of sustainability at coarse scale. (3) Water is an attractive medium around which to design an observation program, and water researchers agree on many characteristics of water-related data needed to advance sustainability science. (4) A program of coupled observation around water will need to be (a) realistic about attainable scope, (b) design data collection scientifically to be representative at useful scale(s) and of both humans and the hydrosphere, (c) leverage existing data collection programs, (d) explore new ways of protecting privacy while enhancing spatial resolution of data and (e) include data on social institutions as well as individuals.

Keywords: *Sustainability science, water data, human-nature interactions, survey research*

Sustainability science is an important new intellectual frontier studying interactions between humans and natural systems (Clark 2007; Kates et al. 2001; Schnoor 2010). These interactions are interesting on their own and critical to harmonizing economic and social development with resource availability and environmental quality. This new field challenges the scientific community to collect data that "encompass[es] different magnitudes of scales (of time, space, and function), multiple balances (dynamics), multiple actors (interests) and multiple failures (systemic faults)" (Martens 2006, 36). I argue in this paper that research at the interface of humans and nature is not adequately supported by existing data collection programs and new programs explicitly designed for coupled research are needed.

As a resource essential to humans but distributed unevenly and unpredictably in nature, water is a compelling medium for the study of human-nature couplings. Braden et al. (2010) call for collecting data on water and humans "across time and space that enable evidence on perceptions, attitudes, social institutions, situation-behavior relationships, and decision-making to be linked comprehensively to measurements of the natural environment."

Due to the complexity of human-nature interactions, most sustainability science has been conducted at small scale through localized observation and analysis. However, many important questions require research at large geographic scales where the effects of climate, terrain, preferences, culture, legal and regulatory systems, information sources, and other spatially and temporally variable factors can be examined. Examples include: (1) how attitudes, preferences and environmental quality interact to influence the evolution of regulatory institutions and (2) how culture and environmental conditions interact to influence human response to information about the environment.

Illustrating Flaws in Current Water Observation Programs

Current data collection programs provide little support for coupled research at large geographic scales. Two examples developed by Braden et al. (2014) illustrate the problem. The examples

investigate whether measured water quality affects environmental attitudes and behavior. The specific behaviors involve recreational choices and household water conservation efforts.

In principle, the findings of studies linking environmental conditions to perceptions, attitudes and behaviors could be important for designing information programs about water that better inform water users. To be useful, however, the data must be representative of the populations and resources of interest with sufficient precision to capture the hypothesized relationships. It will become apparent that existing data sets do not readily meet these standards.

Data Sources

In the U.S., considerable variation in local institutions and cultures as well as in environmental conditions is available through observation at national scale. The U.S. Environmental Protection Agency's (EPA) National Aquatic Resource Surveys (http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey_index.cfm0, Feb. 13, 2013) of streams and rivers, lakes and reservoirs, coastal waters, and wetlands comprise the leading effort to characterize water quality conditions at national scale. They provide point observations on dozens of water quality metrics using sampling frames designed to be statistically representative at national and ecoregional scales. For example, the 2004 to 2005 Wadeable Stream Assessment (WSA) collected data on more than 100 water quality indicators at 2,042 locations nationwide and is representative of water quality conditions at the ecoregional scale (Omernik 1987). These observations are collected in limited time periods and may be influenced by anomalous hydrologic or climatic conditions. They are intended primarily for characterizing trends over time.

To examine behavioral and attitudinal responses to the water quality measurements reported in the WSA, two surveys offer the best available human data at national scale. One of them is the decadal environmental module of the General Social Survey (GSS) (http://www.norc.org/Research?Topics?Pages?environment.aspx, Feb 13, 2013) which is sponsored by the National Science Foundation. The GSS collects demographic, attitudinal, behavioral, and social involvement data through extensive personal interviews. The 2010 GSS sample of 2,044 households is statistically representative of the national demographic profile with some oversampling of minority ethnicities. The second relevant source of social data is the U.S. Forest Service's National Survey on Recreation and the Environment (NSRE) (http://warnell.forestry.uga.edu/nrrt/nsre/clemsc907.html, Feb. 13, 2013). The 2009 round of NSRE provides detailed recreation information as well as demographic data for a nationally representative sample of 103,770 households. The observations were collected by random digit dialing telephone survey administered on a rolling basis from 2005 to 2009.

To protect the privacy of GSS and NSRE respondents, individually-identifiable data are not released. Only data aggregated to census tract (GSS), zip code (NSRE), and county (both GSS and NSRE) scales are available to researchers. Multiple observations within a polygon are averaged, losing information present in the original data. Precise locations and thus, the proximity to specific point observations of water quality, are lost.

People may experience water resources in many different contexts: as drinking water, local geographic features, recreational destinations, and so on. Some resources are experienced near their residences and some further away, so there is ambiguity about the natural environments with which individuals most closely associate and from which they form impressions of water quality. The available social surveys are not conducted with tight couplings of humans and the natural environment in mind and do not collect information that might help identify these associations. Assumptions must therefore be made about the water resources that weigh most heavily in people's impressions of water quality conditions. Based on David (1971), Braden et al. (2014) assume people relate most closely to the condition of surface waters near their homes. Furthermore, since the landscape is laced with more streams than rivers or lakes, people are more likely to reside close to a stream. They therefore assume that nearby stream conditions are most influential and that stream data collected within each respondent's zip code, census tract, or county are broadly representative

of the conditions experienced by respondents, although the WSA, in contrast, does not claim to be representative at scales finer than ecoregions. Based on these assumptions, Braden et al. (2014) geospatially match the social and water quality information. The spatial matching process reveals that WSA and GSS observations were collected in only 4 of the same census tracts and 129 of the same counties; WSA and NSRE observations are collocated in 888 zip codes and 849 counties.

To assemble samples large enough for statistical analysis, Braden et al. (2014) use county-level data for the WSA-GSS match and zip code-level data for the WSA-NSRE match. The resulting samples exclude majorities of the information in the full samples of each individual survey. The WSA-GSS match is further diminished by missing data-only 97 of the matched observations contain all of the requisite information. An immediate concern is whether the matched samples continue to be representative of the nationally-representative samples from which they were drawn. Braden et al. (2014) use Welch's T-test to compare the means of the raw samples to those of the matched sub-samples for 56 variables of particular interest. The tests reveal statistically significant differences for all but 12 variables. Thus, the matched samples are almost certainly unrepresentative of the underlying populations and findings derived from the matched samples are probably not generalizable.

Water Quality, Attitudes, and Water Conservation

Two attitude questions and one behavioral question in the GSS are analyzed by Braden et al. (2014):

1. Is pollution of America's rivers, lakes, and streams?
   a. not dangerous at all for the environment,
   b. not very dangerous,
   c. somewhat dangerous,
   d. very dangerous,
   e. extremely dangerous for environment?
2. How willing would you be to pay much higher taxes in order to protect the environment?
   a. Not at all willing,
   b. Not very willing,
   c. Neither willing nor unwilling,
   d. Fairly willing,
   e. Very willing.

The water conservation question is:

3. How often do you choose to save or re-use water for environmental reasons?
   a. Never,
   b. Sometimes,
   c. Often,
   d. Always.

Braden et al. (2014) separately test three types of water quality indicators for influence on the responses to these questions. A measure of biotic richness is provided by the EPT (Ephemeroptera, Plecoptera and Trichpetra) index (Lenat 1988). Two measures of physical quality are turbidity, measuring light deflection due to particulate matter suspended in water, and the Rapid Habitat Assessment Index, which provides a visually-based overall assessment of stream health (Barbour et al. 1999). Finally, three common chemical measures of water quality are NO_3, phosphorus, and dissolved oxygen.

Braden et al. (2014) separately include each of these three classes of indicators in econometric models of attitudes and efforts to conserve water as described above. Data limitations force them to use the county-level matched GSS-WSA data. They include ecoregional identifiers of the observations to test the possibility of regional differences in the relationships. While several demographic variables (e.g., for attitudes: income, political views, and membership in an environmental group; for water conservation: age, sex, and membership in an environmental group) influence perceptions of pollution danger and conservation behaviors robustly across water quality indicators, not a single one of the water quality indicators themselves significantly affects the perception of danger or conservation efforts. These findings suggest that common water quality measurements collected at nearby streams have little meaning to people as they consider personal water use. Perhaps they pay more attention to indicators other than those considered, or to water bodies other than those where sampling took place, or they may simply be unaware of conditions. In the case of domestic water conservation, it is also quite possible that households decouple their usage of treated water, often drawn from subsurface sources or reservoirs, from the quality of nearby streams. However, another plausible explanation is that data

reduced to county scale in order to support statistical analysis are simply too aggregated and too few to identify relationships that do exist.

Braden et al. (2014) find a significant overall effect, but few regionally-specific effects, from inclusion of the ecoregional identifiers. This result provides evidence of regional differences in water attitudes and behaviors and cautions against generalizing from localized studies.

Water Quality and Recreation

Braden et al. (2014) use WSA and NSRE data matched at zip code scale to study the effects of measured water quality on water-based recreation activities. Zip code scale allows relatively close proximity between people and the locations at which water quality is measured, although the relevance of proximity is questionable as noted above. In addition, some water-based recreation categories defined in NSRE–boating, swimming, fishing, and other waterside activities–are probably pursued more commonly in lakes, reservoirs or coastal waters than in wadeable streams. The conditions of those other surface water resources are assessed by EPA separately from the WSA, and new assessments were underway and not yet available at the time of Braden et al. (2014)'s study. It remains to be determined how researchers might simultaneously use data from multiple assessment programs to identify the most pertinent indicators of water conditions.

Using the matched sample, Braden et al. (2014) find significant relationships between demographic and attitudinal variables and participation in the water-based categories defined in the NSRE: boating, swimming, fishing, and other waterside activities. Almost all of the relationships remain stable across different measures of water quality. However, the water quality indicators themselves are almost always insignificant; the only exception is EPT's positive effect on frequency of swimming. Irrespective of the particular indicator, it is the water quality in wadeable streams nearest survey respondents' homes that most influences their decisions about boating, swimming, and fishing activities seems particularly suspect since some of those activities may be better undertaken at larger water bodies or at locations farther away, but there is little basis in the scientific literature for making alternative assumptions about those geospatial relationships.

These case studies illustrate several limitations of existing data sets for exploring interactions between humans and water resources. First, the aggregation of household data to protect privacy, and to match data spatially when precise locations are not available, sacrifices a great deal of the information available in the full samples. Second, the spatial matching process further reduces the useable data and produces subsamples that are unrepresentative of the full sample and, by extension, the population of interest. Third, the matching process requires linking people to the natural environments (e.g., water bodies near or far) that most influence them, but the information sources provide no basis for mapping those relationships. The obvious solution to these problems is a data collection program designed from the outset to be jointly representative of human and natural systems and to position humans explicitly in relationship to the environmental conditions they actually experience.

Disciplinary Data Aspirations

What would a coordinated program of data collection around water look like? Input on this question was provided in 2011 by a multi-disciplinary convenience sample of water scientists and professionals surveyed by Braden et al. (Forthcoming). Participation in the online survey was invited at a variety of professional conferences and through listserves[1]. Two-hundred and sixteen usable responses were collected over a period of several weeks. Most worked in academic positions, although government, nonprofit, and for-profit organizations also were represented.

The survey asked respondents about their discipline, current work on water resources and the types of data, if any, they use in their work. Disciplines were subsequently clustered into two large groups: (1) natural scientists and engineers and (2) social scientists. The survey also asked respondents to propose research questions they would like to examine. Two types of questions were invited: scientific questions were described as addressing fundamental mechanisms or relationships while policy questions were described as focusing on specific objectives or outcomes. Some respondents suggested questions of both

types. Members of the research team independently conducted content analysis to ascertain the types of data (natural system, human system, or both) required by the stated questions, then reached consensus where their initial assessments differed. The respondents characterized their data needs in terms of frequency of collection (one-time to more-than-decadal), scale (individuals to nations), types of human (attitudes to community conditions) and/or natural system (climate, water, biotic, etc. conditions). Here, we briefly summarize Braden et al. (Forthcoming)'s findings about data aspirations.

Concerning science questions, social scientists emphasize household-level data while natural scientists and engineers prioritize community-level and climate data. For policy questions, surprisingly, natural scientists and engineers among the respondents were more likely than social scientists to emphasize the need for data on attitudes, preferences, group composition and community conditions as well as climate, water quantity and quality and geophysical and biotic conditions while social scientists are more likely to want panel data. Comparing the characteristics of data needed for coupled questions versus questions that were judged to require social data alone, only two differences are apparent: questions requiring only social data are more likely to need attitudinal information while coupled questions are more likely to require panel data. Overall, Braden et al. (Forthcoming) report remarkable interest in social data relevant to water-oriented research questions, even among natural scientists and engineers, and a high degree of agreement in the characteristics of the desired data.

A Coupled Observation Program

Coordinating data collection across scientific domains raises a number of research questions at the outset. First, no such program can encompass all conceivable issues linking people and the environment. It will be essential to narrow the scope of the questions that the endeavor aims to address, then to select variables to measure and record that provide maximal leverage toward the desired scientific program. In a report culminating several years of study to characterize a novel program to observe, measure, and understand coupled interactions between people and the water environment, Dozier et al. (2009) provide a starting point for research on water. Their vision is captured in the following passage (Dozier et al. 2009, 6):

> Transcending the disciplinarily fragmented and place-specific understanding of water that currently exists requires a coordinated and systematic research investment. The objective of the WATERS Network is not to transform all researchers into generalists, but rather to capitalize on the differing perspectives of different research fields. These perspectives can shift our research paradigm from one in which each interacting discipline is treated as a branch with its own knowledge and approaches to a more complete understanding of the coupled human and natural system… by comparing results in different water environments and enabl[ing] advancement through larger-scale, integrated, analyzed data sets that are useful to everyone.

Their ambitious agenda may exceed what is immediately possible.

Second, it will be important to determine the physical scales at which resolution is sought so that data collection can be designed to be representative at the selected scales. Ecoregions were selected for representation in the EPA's National Aquatic Resource Surveys. Along similar lines, for water resources, Hutchinson et al. (2010) propose "Human Influenced Water Environmental Classes" for clustering similar human, hydrographic and ecological features at sub-national scale. In addition to physical and climatic features, they include land cover, population density and human water use among the variables used to define clusters. This methodology warrants further development.

Third, within the desired spatial scale(s), a key issue is to design an observation program that is at once representative of both humans and the water environment. Representation of humans is generally conceived in terms of age, ethnicity, education, and economic profiles. What it means to represent water resources is less clear. The EPA's Aquatic Resource Surveys have wrestled with this issue at least for surface waters and may provide

a starting point for a program that aims at a more comprehensive representation of the hydrosphere.

Fourth, due to fiscal challenges facing the federal government, a new large-scale data collection program comparable to the National Science Foundation-sponsored Earthscope (http://www.earthscope.org/, May 31, 2013) and the Longterm Ecological Research Network (http://www.lternet.edu/, May 31, 2013) is probably out of the question for the near future. To the extent possible, such a program will need to leverage existing data collection efforts of the EPA, U.S. Geological Survey, National Oceanic and Atmospheric Administration, U.S. Department of Agriculture and other mission agencies, in addition to core support from a sponsor of basic research.

Fifth, the program should strive for data protocols that allow more precise spatial identification of human data without violating privacy (Krumm 2009). And, finally, depending on the scientific objectives, it should collect social data not only about individuals, but also formal and informal social institutions such as political jurisdictions, legal regimes, advocacy organizations, and social networks (Braden et al. 2009). These institutions are separable from individuals and extremely important interfaces between water in nature and water in use.

The idea that social and natural systems are co-determined is a central tenet of sustainability science and obviously at work in most water challenges. Current data collection programs in the U.S. do not support generalizable insights about important ingredients of human interactions with water. Coordinating the collection of human and environmental data will be an important step forward in sustainability science and toward strengthening the underpinnings of water management.

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Notes

1. Invitations to the online survey were distributed through conferences (C) and electronic communities (E) of: Agricultural & Applied Economics Association (C), American Political Science Association Section on Science, Technology & Environmental Policy (E), Association of American Geographers (C), Association of Environmental & Resource Economists (E), Association of Environmental Engineering & Science Professors (C&E), Consortium of Universities for the Advancement of the Hydrologic Sciences (E), International Association for Society & Natural Resources (C), Land & Resource Economics Network (E), Society for Conservation Biology (E), Universities Council on Water Resources (E). Participants in an October 2011 workshop on a National Survey on the Water Environment, sponsored by the National Science Foundation, Johnson Foundation, and USDA/NIFA, also responded. Twenty nine percent of 216 survey respondents were referred to the survey by colleagues.

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