INTEGRATING COMMUNITY VALUES INTO SCIENTIFIC MODELS

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Abstract. In this project, we develop a novel methodology for integrating stakeholder knowledge and preferences with a set of constituent hypotheses regarding basic biological, hydrological, and chemical ecosystem processes. Our approach, an extension of regionalized sensitivity analysis (RSA) - a method to determine the sensitivity of model parameters within a bounded range - links qualitative community values with quantitative scientific models. The result will be a general prototype mechanism for integrated assessment, which can inform policy recommendations for improving water quality in the case study, Lake Sidney Lanier.

INTRODUCTION

Lake Sidney Lanier is a multi-use recreation, water supply, hydro-power, navigation, and flood control reservoir northeast of metropolitan Atlanta. This area has one of the fastest growing populations in the country and currently faces many land-use planning decisions. These pressures have brought much attention to the area (Hatcher, et al. 1994, Kundell et al., 1998, Limno-Tech, Inc. 1998). A rich data set of water quality parameters has been assembled using these and other secondary sources (Xiao-Qing and Rasmussen, 1999). Development affects physical characteristics of the lake primarily through increasing impervious surface area and increasing sediment and nutrient runoff, and it also affects the perception of local homeowners' quality of life.

The interface between stakeholders and expert scientific knowledge is an important link in managing for a sustainable environment. This two-way communication relies on an integrated adaptive, experimental management strategy (Holling et al. 1978, Lee 1993, Gunderson et al.1995) to enable effective decision making. It is common to include community sentiment through public hearings and meetings, but an ongoing iterative feedback of community preferences is often lacking. Here, we propose a method to incorporate qualitative knowledge acquired by stakeholders through use and participation in their local environments by forward-matching these values against scientific predictions (Beck, et al. 1998,). This intuitive and experiential knowledge has traditionally been considered too anecdotal and therefore excluded from scientific models, but here we propose a methodology to integrate ecological, hydrological, and social/policy sciences in an interdisciplinary study of a rapidly urbanizing watershed community. The specific objectives of this research are to:

- identify the key scientific parameters that influence the likelihood of desired and feared future states as indicated by community preferences
- improve understanding of basic lake ecosystem behavior, in particular, the role of the microbial foodweb and sediments in nutrient cycling; and
- develop a decision making process that incorporates both short- and long-term community values into scientific models.

Success in the last of these would culminate in an "adaptive community learning" framework which could support an ongoing iterative process among scientists, stakeholders, and decision makers. The major components of the study include an ecosystem foodweb model of the reservoir, a survey instrument to elicit stakeholder values, modest experimental sediment chemistry work, and most importantly, coherent integration of these parts. A general overview of major pieces of the project and the methods used to address these question are described.

BACKGROUND

Model

A computer simulation model of the lake ecosystem is being developed. The model takes its principal, constituent hypotheses from definitive ecological studies of Lake Oglethorpe, Georgia (Porter, 1996) with special reference to the role of the microbial loop in the overall dynamics of the aquatic foodweb. The reservoir foodweb is represented by a seven compartment model: nutrients, primary producers, herbivores, invertebrates, vertebrates, detritus, and sediment. A detailed conceptualization of the model is described in these proceedings (Osidele and Beck, 1999). An accompanying definition of past behavior for Lake Lanier (initially Lake Oglethorpe) is being assembled from an experimental data base and expert knowledge. Regionalized Sensitivity Analysis (RSA), described in detail below, is used to match (or reconcile) model output with these system behavior definitions. The RSA will also be used to match model projections with stakeholder-derived definitions of future system behavior. Significantly, these behavior definitions are to be obtained from qualitative community survey data.

Community Survey

Various Lake Lanier stakeholder groups and decision making organizations have been contacted in regards to this study. One citizen group in particular, has been identified as being representative of the lake community. A survey instrument for eliciting both short- and long-term community values and preferences is in the final stage of development and will be passed to this group in early 1999. Preliminary results are expected to follow by late spring, 1999. From a social theoretical perspective we have been especially concerned to achieve balance in the survey between minimal "tainting" of these prior stakeholder beliefs and well-directed guidance for formulating (future) system behavior definitions appropriate to the state variables of the model.

Field Experiments

For Lake Lanier any number of prior scientific uncertainties could have been chosen as the most worthy of further investigation with limited funds for research. We opted to examine, through laboratory-based experiments, the processes affecting the attachment and release of phosphorus to and from sediments, finding that phosphorus binds quickly (almost instantaneously) to sediment particles in oxic conditions (Carruba, 1998). A plan is underway to repeat these tests under anoxic conditions and compare the results to a geochemical equilibrium model of these processes. Also, a testable hypothesis for the vertical dissolved oxygen profile in the lake has been developed. Our hypothesis, that differential respiration in the water column results in the inverted dissolved oxygen profile, contradicts a major recent study which concluded that density currents are responsible for the phenomenon (Limno-Tech, 1998). This may be significant because in the Limno-Tech model nutrient rich inflow "plunged" directly into the lower hypolimnion layer of the stratified lake which resulted in considerably lower than observed loading levels in the upper epilimnion layer.

Integration

A central methodological component of our project involves application of the model and RSA to determine on which key scientific unknowns might turn the reachability of the hopes and fears of the community for the future quality of Lake Lanier. It is in this manner-by seeking to reconcile the science base encoded in the model with the so-derived target future behaviors- that the concerns of the stakeholders are driven into the core of our quantitative studies of hydrology and ecology. The survey and model are being developed in the framework of a new decision making tool that incorporates sound science with qualitative community values. In this decision making framework the long term stakeholder preferences are the basis for a community vision (ends) and provide a mutually agreed upon boundary for short term action oriented needs (means) of stakeholders (Coffin et al., 1999). As a result, an iterative process is established consistent with our broad goal of adaptive community learning.

METHODS

In this section, we introduce the methodology by addressing three key questions of this project.

How can qualitative hopes and concerns of the community be integrated into a scientifically based ecosystem model in a consistent decision making framework?

Community values will be elicited through a written survey. Basic demographic and lake use activity data will be used to standardize information. Open ended questions give the respondents the opportunity to sketch their ideal vision of the lake community. Targeted questions are used to rank concerns regarding a range of water quality issues such as sedimentation, algal blooms, unsafe bacteria levels, changes in fish stocks, introduction of exotic species (e.g. zebra mussels). This qualitative and rank quantitative data will be used to define the stakeholders' desired and feared future behavior of the lake.

A role for this category of qualitative data was developed by Hornberger and Spear (1980) in the context of model parameterization. They used qualitative historical field data and expert knowledge to determine a definition of past system behavior. The RSA was used to test many different parameter combinations. Combinations resulting in model output meeting the behavior definition were noted from those that did not. Patterns emerged indicating the relative sensitivity of the model to its various parameters. They suggested using this information to guide refinement of the model and data collection by identifying parameters that are most sensitive to meeting the observed (history-matching) system behavior.

Here, we expand on that initial application of history-matching observation with model dynamics to identify parameters that are most sensitive to meeting the desired (future-matching) system behavior based on community surveys (Beck et al. 1998). Stakeholder expressed concerns and preferences for a range of issues are matched against the likelihood of these behaviors manifesting in the model output. For example, if the respondents rank sedimentation as a primary concern, then only models which exhibit sedimentation in the appropriate range are considered to meet the behavior. This procedure is repeated thousands of times, each time using different randomly generated parameter values. From this information, a mosaic is painted indicating which parameters are likely to influence the model realizing the stakeholder concern or not. These parameters are identified as key to incorporating stakeholder views and draw the attention of further investigation. Similarly, a system behavior definition of stakeholder preferences will be developed and tested using the RSA. In this manner, the stakeholder concerns and preferences are directly included in the modeling process.

Do citizens value the environment differently over different scales of space and time, and how can the consequences of these differences be explored in the context of a science-based model, especially in respect of issues associated with system behavior in the longer term?

Stakeholders value the environment differently relative to their perceived role in the specific interaction (Norton et al, 1998). As consumers, stakeholders are likely (in spite of the rise in "green consumerism") to take a use oriented or exploitationist view. However, after removing themselves from the immediate circumstances, they are more likely to see themselves as citizens emboldened with stewardship responsibilities. The dilemma is how to get individuals to express both positions simultaneously. A common method is to determine willingness to pay for specific environmental services. A recent survey of Lake Lanier Association members showed that eighty percent of respondents would be willing to pay more in fees for stronger environmental regulations to protect water quality (UCBG, 1997). However, this standard cost-benefit analysis does not capture the essence of long-term intergenerational equity, nor is the economic time scale appropriate for ecological dynamics (Norton, 1995).

Here, we distinguish the stakeholder between consumer and citizen by framing the question as desires and concerns in the short- (2-5 years) and long-term (25+ years). It is hoped that in the light of the long-term perspective the stakeholders will distance themselves personally and respond to the situation as informed citizens. In this way, we move beyond preference based economic models in order to understand stakeholder values as an ongoing iterative process. The system behavior definitions described above will be formulated for both the short- and long-term concerns and preferences of the stakeholders to determine if they do indeed value the envimment differently over these scales.

How do community values change with time, not only in response to discussions amongst community members, but also as a function of interaction with the science base (specifically models of the system's supposed behavior)?

Clearly, stakeholder preferences are not constant. Active participation in an interest group could sway one's position toward the goals and perspective of the group. This is a form of social learning. Also, exposure to additional scientific information could alter one's beliefs. However, if we assume that individuals self-select for information which supports their preestablished views, new counter-vailing information would have to be actively disseminated for it to reach its target audience. We are also proposing additional methods for studying long-term environmental values in order to better understand stakeholder values as an ongoing iterative process (Norton and Steinemann, forthcoming). In this approach, multi-criteria analysis will be used to track how individual mental models and preferences change over time and to identify alternative development paths or scenarios.

In the current project, the survey instrument will be administered twice with the hope of capturing the results of these learning processes. The survey and model results will be presented to the stakeholders with an emphasis both on informing them and tracking their response to participation in an educational group dynamic. The exact education mechanism has not been decided upon, but could include the release of the survey results, a demonstration of the model performance, or an interactive modeling workshop. Each strategy has different strengths and weaknesses based on cost, time, and extent of exposure. This iterative feedback between science and society results in a winnowing process that allows for future research to be more targeted toward the key unknowns relevant to community values.

CONCLUSIONS

Integrated assessment is a management strategy that interfaces scientific information, decision makers, and stakeholder groups. This field developed largely in conjunction with global climate change research with an early emphasis focused on linking science and decision makers. In general, an instinctive reaction is to highlight a model's predictive capabilities to assuage decisions makers who are looking for directional policy alternatives based on model results. However, there has been a trend to use the integrative and modeling process itself as an education tool. More recently, the important role of stakeholders is being given due attention. Here, we propose a methodology to directly incorporate community values into the scientific modeling process in order to identify the key parameters likely to influence the reachability of these future preferences and concerns. The match and mismatch of both short- and long-term community values will be used to recommend appropriate management scenarios. Results from this study should further the development of integrated assessment methodology and positively impact water quality issues associated with Lake Lanier.

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