The Scientific Method in Locally-Based Monitoring Programs: Lessons Learned from an Analysis of Water Quality Data from the May River

Environmental monitoring plays a crucial role in conservation and natural resources management. Monitoring activities have historically been centralized in federal and state government agencies, but increasingly, locally-based monitoring and research has been advocated as an alternative offering greater responsiveness to and buy-in from local stakeholders (Danielsen et al. 2005a,b; Silvertown 2009). As with any such effort, care must be taken when designing locally-based monitoring and research projects to ensure data are of sufficient quality to address the issues of primary concern (Sharpe and Conrad 2006; Lindenmayer and Likens 2009). The scientific method provides a powerful and efficient framework for management-centered inquiry (Yoccoz et al 2001; Nichols and Williams 2006), but it is often overlooked during critical design stages of monitoring programs at all levels. An ongoing monitoring and research program in May River watershed illustrates both the successes of a locally-based approach and the advantages to building these efforts around the scientific method.

The May River, a tidally-dominated system located in Beaufort County, SC, is an important economic, recreational and cultural resource for local citizens (Town of Bluffton, 2008) and is designated an Outstanding Water Resource (SCDHEC, 2001). In response to rapid population growth and development in the May River watershed, this community has taken a series of progressive steps to address the potential consequences of these changes (Beaufort County, 2007; Town of Bluffton 2008). As part of this, the Town of Bluffton and the Palmetto Bluff Development initiated water quality monitoring programs to identify development-related impacts to the important natural resources of the May River. As data accumulated from these programs, local stakeholders found it difficult to identify the answers they sought. At the request of the Water Quality Technical Advisory Committee organized by the Town of Bluffton, South Carolina Department of Natural Resources (SCDNR) staff reviewed the water quality programs, framed the primary programmatic questions, compiled and analyzed all relevant available data, and provided recommendations for program improvement.

The SCDNR review identified three core questions: 1) are significant changes in water quality occurring in the May River?, 2) are developed drainages acting as significant sources of pollutants to the May River system?, and 3) what monitoring efforts will be most valuable and feasible to continue in the future? Local stakeholder data sets included continuous measures of physical water quality (salinity, temperature, pH, etc.) and point measures of physical water quality, nutrients and fecal coliforms collected in the main stem of the May River, several smaller tributaries and headwater creeks. These data were centralized, quality assured, and statistically analyzed. Data from several existing state and national water quality programs as well as land use and climatological sources were also used to enhance and expand the analyses.

Several significant spatial and temporal trends in water quality were detected. Contrary to local expectations that salinity was decreasing due to increased stormwater inputs, salinity was found to be increasing over the last 10-15 years in the May River. This pattern largely reflected decreasing regional rainfall patterns, but the resolution of the available data sets prevented the elucidation of direct links between estuarine salinity and rainfall, land use and stormwater in the May River watershed. Fecal coliform bacterial levels were also found to be increasing in the river as a whole. The concentrations of fecal coliform bacteria were highest and the increases were most apparent in the upper and middle portions of the river where upland development is more concentrated and changing more rapidly and river volume is lowest. Although this trend may be a reason for concern, especially if the pattern begins shifting downstream, fecal coliform levels in the May River remained similar to effluent-free waterbodies of similar size within the Beaufort County. Nutrients and other physical water quality measures showed little evidence of changing at the few locations where those data were available.

Levels of fecal coliform bacteria, total nitrogen (TN) and phosphorus (TP) and turbidity from developed drainages showed a clear difference north and south of the river. South of the river where development is recent and lower-density, fecal coliform bacteria were highest in undeveloped drainages during both routine sampling and following rain events, likely reflecting a wildlife source. TN, TP and turbidity were generally highest in drainages originating from a waterfowl impoundment. North of the river where higher-density development largely pre-dates adoption of more stringent stormwater BMPs, fecal coliform bacteria, TN, TP and turbidity were all significantly higher in developed drainages relative to the undeveloped and developed drainages south of the river. On the north side the river, pollutants generally increased in drainages located further up within the watershed where turnover times would be longer. These data indicate that pollutant levels present in the May River and its tributaries reflect a complex interaction between land cover/land use and the physical characteristics of receiving waterbodies.

A number of recommendations were proposed to decrease cost and effort and increase the ability of water quality monitoring to address local stakeholder concerns. These recommendations included ceasing several monitoring elements that either proved less-informative or succeeded in addressing a specific concern (ie, the data answered the question), while expanding others that stakeholders felt most closely reflected their continuing needs. Recommendations also included improving quality assurance/quality control of datasets and ensuring consistency of methods and data quality across monitoring elements. Broadly, the longer-term monitoring strategy should involve a coordinated effort among the various stakeholders that builds on existing local and state programs and focuses on key resources and variables of primary concern.

One of the primary recommendations was to guide future water quality monitoring and research in the May River watershed using a structured application of the scientific method. Such an approach should: 1) identify clear and focused questions, 2) state a priori hypotheses about system state differences and the effects of management action, 3) utilize rigorous study designs and analytical methods to directly test the hypotheses, and 4) inform further questions and research approaches. Questions and *a priori* hypotheses focus effort around central themes thus preventing the unnecessary waste of time and funds and ensure data are appropriate to address the issue of concern. Meaningful interpretation relies on application of basic study design principles (controls, replication, reproducibility, etc) and analytical methods (data structure, statistical approaches, etc) that directly address the stated hypotheses. This requires significant technical expertise, but without appropriate design and analysis, the objectives of a study are not likely to be met. Finally, the scientific method is inherently cyclical thus previous research informs decisions in the short-term but also shapes further questions, hypotheses and methods in the long-term. In effect, a local monitoring program should be designed so that it can adapt to an evolving understanding of the natural and human system. Several examples of both successes and shortcomings will be presented that illustrate the importance of these crucial steps in designing locally-based monitoring programs. Similar discussions have taken place in the scientific literature primarily with respect to the conservation and management of biological resources (Yoccoz et al. 2001; Nichols and Williams 2006). With the increasing role of participants at the local level, consideration of these issues is also critical for water quality monitoring and research programs (Herron et al. 2003).

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