The Challenge of Communicating Monitoring Results to Effect Change

Shawn L. Carter, Giselle Mora-Bourgeois, Todd R. Lookingbill, Tim J. B. Carruthers, and William C. Dennison

The Natural Resource Challenge legacy

SINCE ITS INCEPTION, the National Park Service (NPS) has been charged with preserving the natural and cultural heritage of the United States for future generations. It is only recently, however, that the NPS has fully embraced the need to understand and describe the ecology of parks. The infusion of an ecological perspective into the natural resource management of the national parks is what separates today's park management from much of that which preceded it (Sellars 1997). The guiding principles set forth by the agency's National Leadership Council as part of the Natural Resource Challenge (NPS 1999; hereafter "the Challenge") shepherded these perspectives into present NPS culture and practice. Ultimately, the insights, common goals, and collaborations we describe in this essay have all been made possible by the vision and funding of the Challenge, the most recent high-water mark for embracing science within the NPS.

In this paper, we discuss a special collaboration enabled by the Challenge, in which an inventory and monitoring (I&M) network (National Capital Region Network; NCRN), a research learning center (Urban Ecology Research Learning Alliance; UERLA), and a cooperative ecosystem studies unit (Chesapeake Watershed CESU) partner (University of Maryland Center for Environmental Science; UMCES) coalesced around a common goal: to collect, analyze, and interpret data in national parks, and to promote learning and understanding. We describe a set of tools and principles for integrating and communicating science that we believe have broad utility in the practice of natural resource stewardship. Furthermore, we stress the iterative and collaborative nature of communicating results and how the process of communication leads to shared investment and stimulates new areas of scientific inquiry.

Recognizing the need to communicate scientific results

Although the NPS I&M networks were not explicitly charged with developing communication products, sharing scientific results is a logical and necessary outgrowth of natural resource monitoring because the results need to be used for making management decisions. Simply collecting data—or even increasing our ecological understanding—will not necessarily help us reach our ultimate goal of informing management practices. As the Challenge aptly states, "Once this information is in our hands, we must share it widely, so that child and adult, amateur and professional can benefit from the knowledge uncovered in these places" (NPS 1999).

A shared goal of all the Challenge programs (e.g., inventory and monitoring programs, research learning centers, exotic plant management teams, and cooperative ecosystem studies units) is to integrate science and management. Achievement of these goals will greatly depend on the internal capacity of individual parks to gain and share knowledge. Thus, incorporating scientific information into management decisions requires not only the transfer of information in the form of organized, interpreted data, but also a contextual framework that embraces the experiences and values of managers and the public. Now more than ever, we NPS heirs to the Challenge must show that we are acquiring the information we need, and that our ability to protect resources has improved. We believe that a sound communication strategy, using interesting, synthetic, and contextualized products, will not only serve managers' needs, but also sustain public trust and promote public scientific literacy.

The three principles of science communication

The need to communicate monitoring results led the NCRN and UERLA, in tandem, to collaborate with the Integration and Application Network (IAN) based at the UMCES. The IAN is an interdisciplinary team of scientists working to transform raw data into synthesized information and to communicate findings in effective ways to promote knowledge-building (Thomas et al. 2006). Each step of the process involves key stakeholders and uses three basic principles of science communication: visualization, contextualization, and synthesis (Thomas et al. 2006). Below, we describe how these principles can be applied to help provide a comprehensive understanding of monitoring results. In this paper, we illustrate the application of these principles with reference to our shared experience in the National Capital Region.

Visualization. The purpose of visualization is to answer the questions, "who?", "what?", "where?", and "when?" so people can understand *"why?"* Visualization elements include conceptual diagrams, maps, photos, extended legends, charts, and graphs. Each type of visualization plays a different role in describing ecological phenomena; collectively, they create a comprehensive explanation that no single chart, map, or photo can provide. Thus, the process of communicating science becomes less audience-specific, because all readers are likely to be able to view results in a format they prefer.

Conceptual diagrams provide a particularly effective means of combining diverse types of information into an integrative science understanding. They are "thought drawings" underpinned by actual data. A conceptual diagram is similar in many ways to a traditional conceptual model (e.g., box-and-arrow model) but has a few fundamental differences (Figure 1). Like conceptual models, these diagrams show important components of ecological systems. They can show processes, pathways, flows, and indicators, as well as interactions between them. Also, conceptual diagrams can include several levels of complexity (similar to sub-models) that show particular phenomena in greater detail. A primary difference between conceptual models and diagrams is the use of visual elements. Whereas models generally employ standard geometric shapes to depict drivers, stressors, regulators, and other elements, conceptual diagrams use more intuitive symbols to represent data and key results, with a suite of

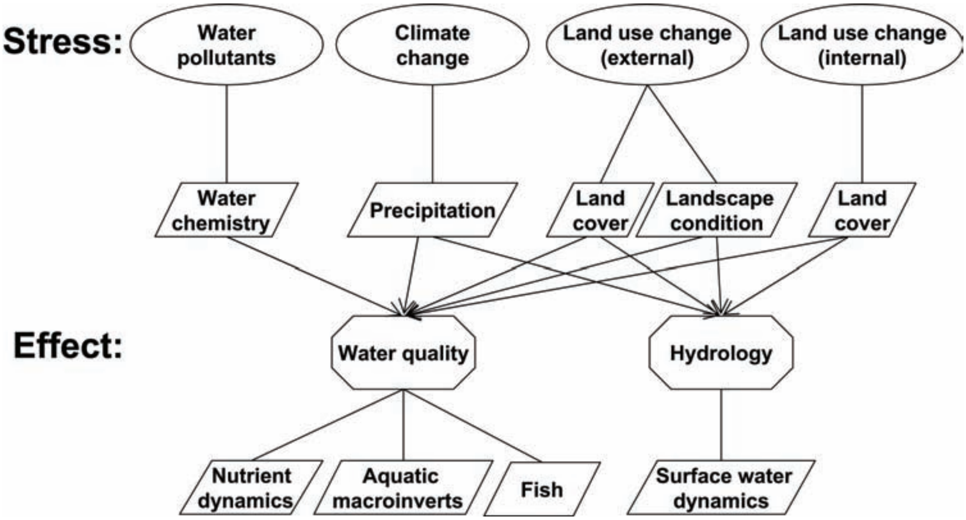


Figure 1. A comparison between a conceptual model (above) and a conceptual diagram (facing page) for water quality. Both graphics are supported by data and show linkages among key indicators, processes, and threats. The judicious use of symbols and an extended legend in the diagram improve understanding and aid visualization of the primary issues.

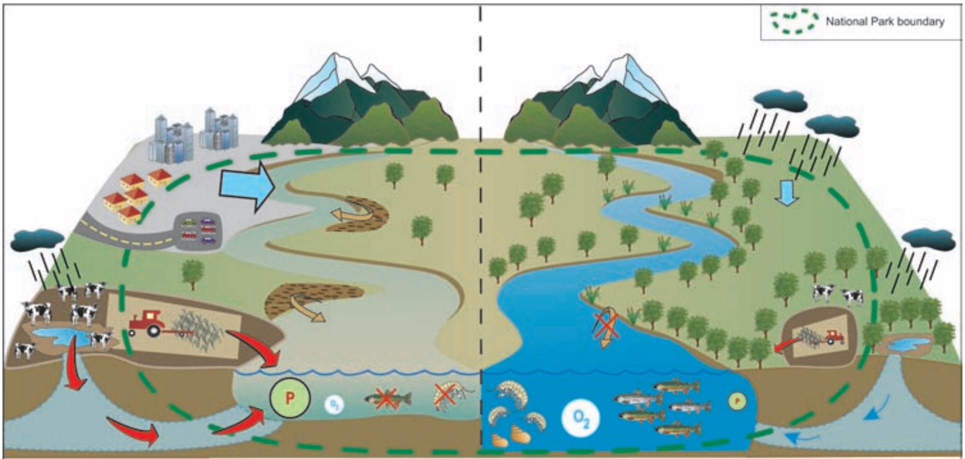
symbols that either provide a graphical (i.e., lifelike) representation or demonstrate an abstract process (e.g., arrows denoting flows).

Symbols are unambiguous and can be easily shared, thereby promoting a consistent message among different programs or perspectives. Symbols can also be used independently of language and explanations; over time, a comprehensive collection of symbols can essentially represent an unspoken language (see http://ian.umces.edu/symbols/). In addition to design, the placement, size, and number of symbols used also convey meaning. Larger size and greater numbers can indicate more significance, while placement provides geographic context (see "Contextualization," below). Both conceptual models and conceptual diagrams are useful tools for defining ecological systems, but the intuitive, universal appeal of symbols improves understanding and attracts a broader audience to carefully crafted conceptual diagrams.

Contextualization. Providing appropriate context is essential for communicating complex ecological monitoring data that have many interrelationships in space and time. Context adds to visualization by personalizing an issue; different types of context can offer a unique understanding depending on the audience's perspective. We discuss three types of context: thematic, geographic, and indicator-based.

Conceptual diagrams provide necessary thematic context. They are stylized and often transferable beyond the immediate study site. For example, a conceptual diagram of an urban environment has appeal and applicability not only to the National Capital Region but also to other urban parks throughout the country. We have constructed ecological stories, or "vignettes," that are pertinent to NCRN parks and also have broad appeal. A thematic overview of stressors on water quality associated with

HABITAT: WATER QUALITY



IMPAIRED STATE	VITAL SIGNS	DESIRED STATE
HIGHLY VARIABLE Impervious surfaces alter the timing and magnitude of stream flows	surface water dynamics	STABLE Intact watersheds and few point sources buffer streams against flood events
UNSUITABLE FOR BIOTA Upstream and surrounding land use can impair core water parameters	water chemistry	SUSTAINS BIOTA Clean water allows for sustainable populations of biota
EUTROPHIC High inputs of nutrients result in eutrophication	nutrient dynamics	OLIGOTROPHIC Intact forests and wetlands filter out nutrients
DEPAUPERATE AND DISEASED Poor water quality reduces diversity and abundance of macroinvertebrates	aquatic macroinvertebrates	DIVERSE AND ABUNDANT An abundance of macroinvertebrates indicate good water quality
LOW Shallow and scoured stream beds and eroded bank sides reduce habitat quality	physical habitat index	HIGH Deep water, intact stream substrate, and stable banks provide good habitat
DEPAUPERATE Poor water quality reduces diversity and abundance of fish	fish	DIVERSE AND ABUNDANT Diverse and abundant fish populations are found in high water quality streams

an urban setting provides a useful context for interpreting the monitoring data being collected in the NCRN (Figure 2).

Maps and photos with extended legends provide geographic context. Good maps and appropriate photographs have tremendous value because they explicitly address spatial scale. Using carefully placed, synthesized data on a map is one of the best ways to show relevance and integration (Figure 3). Maps allow us to visually integrate the human and natural realms. Through maps, we can also speak to people's sense of place, facilitating connections and allowing comparisons. Photographs provide an additional sense of place that maps and graphs cannot capture. Photographs also enhance unique perspectives that the casual visitor would not be able to experience otherwise (e.g., aerial, underwater, macro-scale, or historical; Figure 4).

Another form of context can be based on environmental indicators themselves. Using an indicator-based context helps to

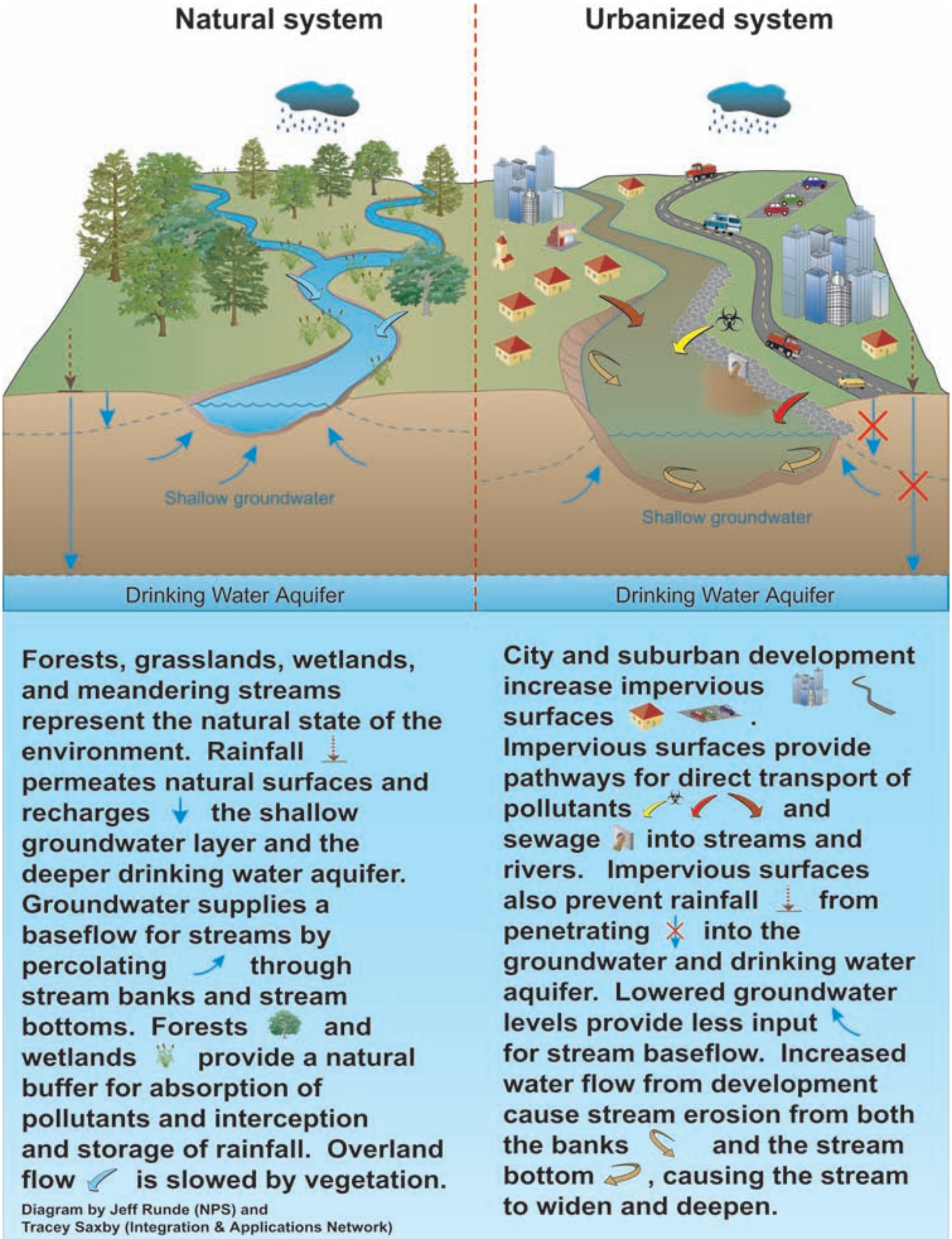


Figure 2. A theme-based conceptual diagram showing urban threats to water quality. While especially relevant to the National Capital Region, processes and threats can easily be generalized to other regions or parks.

PRINCE WILLIAM FOREST PARK

Prince William Forest Park is the largest protected example of Piedmont forest in the National Park System. The 19,377 acre park in northern VA also protects the Quantico Creek watershed, and is a sanctuary for numerous native plant and animal species. Because the park includes two physiographic provinces (Piedmont and Coastal Plain) and lies in the transition zone between northern and southern climates, it exhibits a wide range of vegetative communities, including rare seepage swamp habitat and remote stands of eastern hemlock with old-growth characteristics. Major threats to park resources include adjacent land development, noise pollution, and the introduction of invasive species and disease.

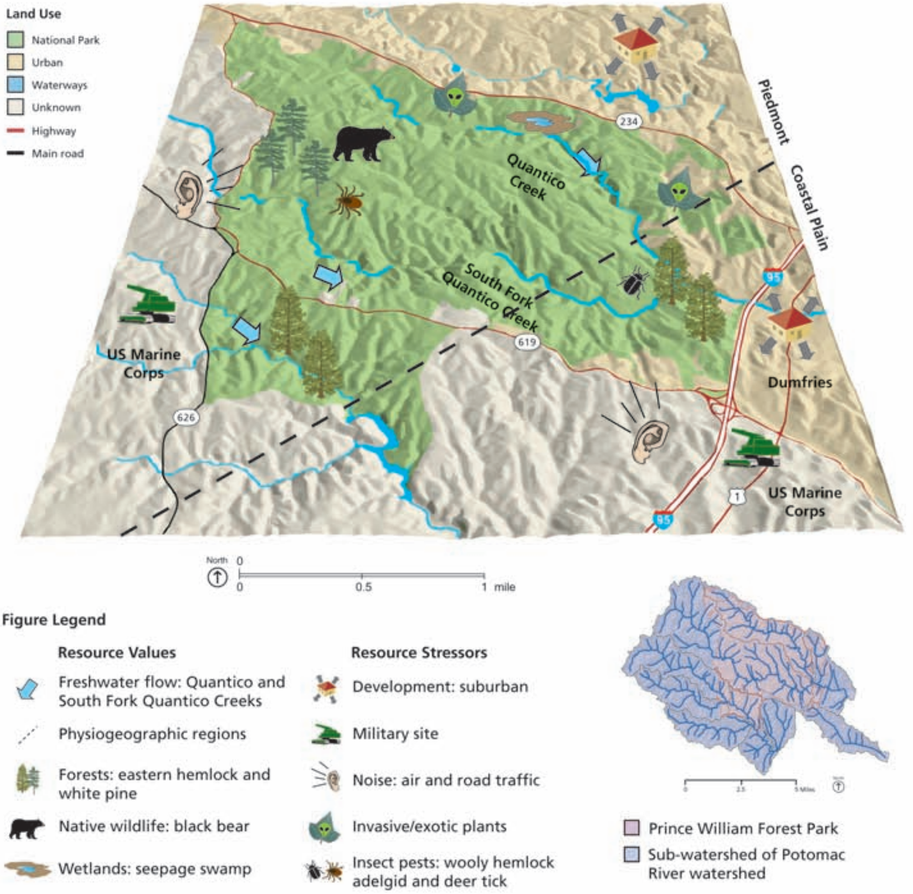


Figure 3. Spatially explicit map for Prince William Forest Park. Symbols are used to locate and show relative importance of park resources and threats. Broader geographic context is given by showing the broader surrounding watershed (Potomac) and key physiographic zones (Piedmont and Coastal Plain).

Figure 4. Aerial photos that portray geographic context show that adjacent development can impact national parks within urban areas. Photo courtesy of Tom Paradis.

address the continual challenge of defining what is being monitored (e.g., a vital sign) versus what is being measured (e.g., a metric). For example, if the indicator of interest is water quality, then many measures may be considered (e.g., dissolved oxygen, contaminant levels, nutrients, or ionic concentrations). Thus, a broader suite of variables offers context to help readers to better understand each indicator and how it relates to other vital signs and a much larger ecological framework (Figure 5).

Synthesis. Decision-makers don't need all the data related to a subject; they need relevant data. This is why providing synthesis is particularly important for achieving science-informed management decisions. More than an academic exercise in data analysis, proper synthesis is a "process of relating." Several rules of thumb shape our choices for how to synthesize data:

- **Naïve audiences are not stupid audiences.** Credible science and technical detail underpin the collection and analysis of monitoring data, and such a foundation is crucial to understanding results. Effective communication attempts to maintain high standards of quality without sacrificing clarity.
- **Technical detail is not necessarily clutter.** Details add value when appropriately presented. On the other hand, simply adding more data and results does not equate to adding more value, insight, or significance.
- **A simple conclusion is not a simplified one.** Audiences will appreciate the distillation of results into meaningful

conclusions, but this does not require "dumbing down" the message.

- **Jargon does not bolster scientific credibility.** Rather, the effective presentation of results relies on common sense, logic, and reason.

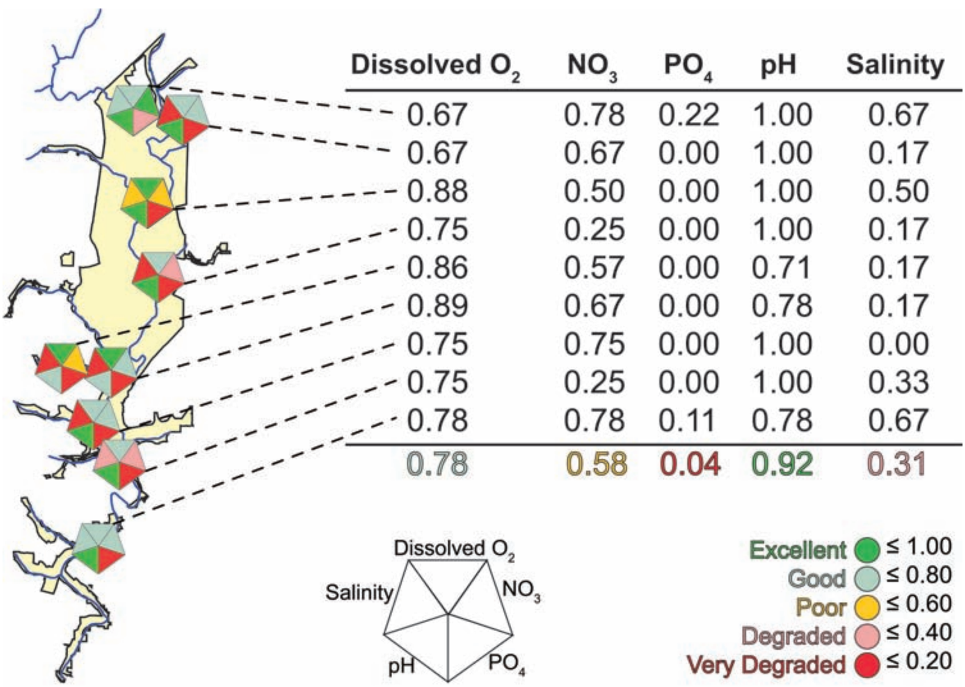
Visual elements (e.g., charts, graphs, symbols, and extended legends) effectively address these guidelines and are essential tools for relating results and meaning.

The internet offers a powerful opportunity to blend verbal, quantitative, and qualitative elements to achieve visual and cognitive synthesis of data. Information pathways can offer different types of context for synthesis: *conceptual* (theme-based), *geographic* (place-based), and/or *indicator* (attribute-based). This approach to synthetic data offers the advantage of providing access to information in different ways, depending on the interests of the end user (Figure 6).

Theme-based synthesis uses conceptual diagrams to provide linkages between the data and universal or generalized ecological concepts (e.g., biogeochemical cycles, climate variability, land use dynamics). Theme-based diagrams indicate commonalities among indicators or processes, describe broad-scale, complex ecological relationships, and are more likely to draw upon data for a suite of indicators (e.g., air quality) than any particular attribute.

Place-based synthesis uses spatially nested, georeferenced diagrams to define

Figure 5. An ecological assessment for water quality data at Rock Creek Park. Data shown represent the percentage of time when measurements fell within acceptable state regulatory standards. Individual measures of water quality are shown together in a spatially explicit form. This format conveys measure-specific information while also showing how measures relate to one another.



Dissolved O_2	NO_3	PO_4	pH	Salinity
0.67	0.78	0.22	1.00	0.67
0.67	0.67	0.00	1.00	0.17
0.88	0.50	0.00	1.00	0.50
0.75	0.25	0.00	1.00	0.17
0.86	0.57	0.00	0.71	0.17
0.89	0.67	0.00	0.78	0.17
0.75	0.75	0.00	1.00	0.00
0.75	0.25	0.00	1.00	0.33
0.78	0.78	0.11	0.78	0.67
0.78	0.58	0.04	0.92	0.31

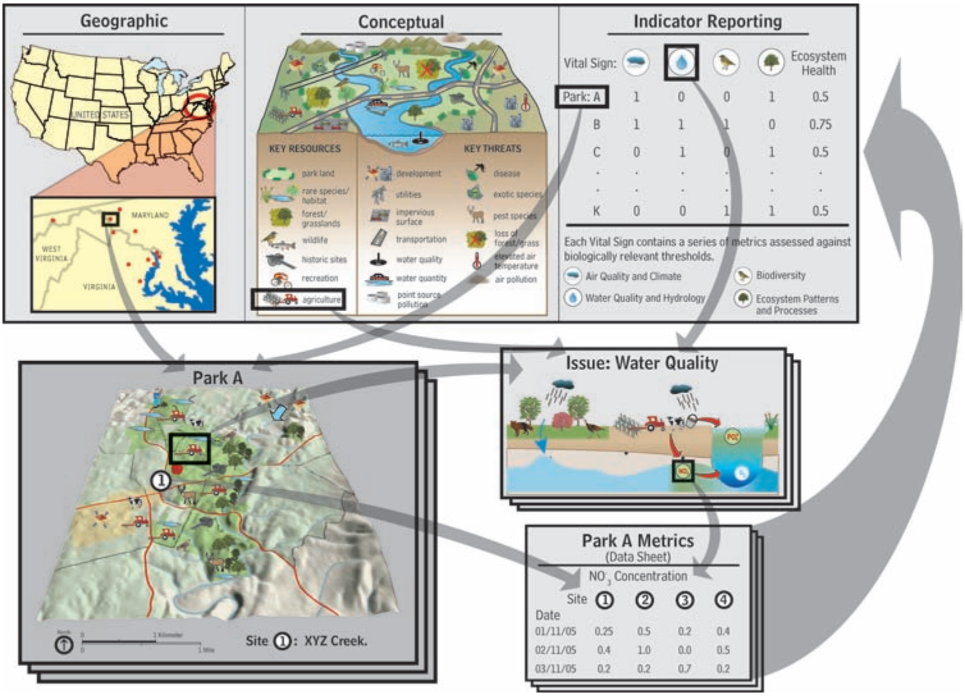


Figure 6. Overall framework for obtaining synthesized data using multiple navigation pathways. Park conceptual diagrams are linked by a geographic map and appropriate monitoring indicators. Ecological themes ("vignettes") become sub-models to illustrate park-based issues within a regional context. Data support the entire framework and can be queried and summarized according to the navigational path chosen (after Dennison et al., in press).

the spatial extent of the data being accessed. A major benefit of a place-based navigation pathway is that it allows users (e.g., park managers) to easily determine where data are being collected within a park, which provides context for related monitoring or research efforts.

Indicator-based synthesis selects data according to a particular attribute of interest. Data may be accessed at hierarchical levels depending on the needs of the user. A person searching for information on water quality, for example, might find data on a suite of different indicators. Alternatively, a person could also access data for a particular indicator of interest (e.g., dissolved oxygen). Indicator data also can be cross-linked to maps and conceptual diagrams using symbols to provide attribute information for specific locations (place-based) or conceptual ideas (theme-based).

Why the IAN-NPS model works

We have purposefully adopted a series of principles that will help us align the capabilities, interests, and needs of researchers, managers, and citizens. The result is a communication strategy that creates, verifies, and applies new knowledge. Our goal is not only to transfer information in the form of organized, interpreted data, but also—and more importantly—to assist with thinking about that information and to build shared understanding. The distinction we make between transferring information and generating knowledge is important. Generating knowledge requires a conceptual framework that both incorporates existing data and captures the experiences, values, and context of researchers, managers, and the public alike. We believe that it is the process of shared knowledge-building, rather than the simple transfer of information, that improves the capacity of managers to make informed decisions and therefore invoke more effective actions.

Our process for communicating science is a team effort, takes time, and produces tangible results. Scoping workshops with park resource managers and interpretive staff have been used to create and refine conceptual diagrams (Lookingbill et al., in press). The NCRN has played a large role in contributing synthesized data, the UERLA has worked closely with park staff to construct and understand the models, and UMCES, our academic partner, has been instrumental in evaluating and improving our models. Conceptual diagrams have been invaluable for establishing a common understanding of resource values and priorities. The very process of defining appropriate symbols for indicators, deciding where they should be placed and how large they should be, and seeking agreement among those outside the park, though time-consuming, has created a shared vision for monitoring priorities in the region. While driven to produce particular products (e.g., conceptual diagrams, newsletters, booklets, posters, a website), we have found that the process of creating these products has generated and reinforced an effective collaboration. This gives rise to our recommendation that each stage of a collaborative program should have a product focus to maintain and enhance the collaborative process.

No single communication tool can provide everything needed to promote informed environmental stewardship. Just as each of our partners has brought an integral component to our communication strategy, each product addresses slightly different needs based on the individual perspectives of the greater public. Newsletters, booklets, posters, conceptual diagrams, charts, figures, and websites are all valuable tools. By incorporating key principles and guidelines into each of these products, a consistent, broad-reaching message can be communicated, providing proof positive that the NPS is living up to “the Challenge” of preserving our shared natural resource legacy.

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Shawn L. Carter, National Park Service, National Capital Region, Center for Urban Ecology, 4598 MacArthur Boulevard NW, Washington, D.C. 20007; shawn_carter@nps.gov

Giselle Mora-Bourgeois, National Park Service, National Capital Region, Center for Urban Ecology, 4598 MacArthur Boulevard NW, Washington, D.C. 20007; giselle_mora-bourgeois@nps.gov

Todd R. Lookingbill, Appalachian Laboratory, University of Maryland Center for Environmental Science, 301 Braddock Road, Frostburg, Maryland 21532; tlooking@al.umces.edu

Tim J. B. Carruthers, Integration and Application Network, University of Maryland Center for Environmental Science, P.O. Box 775, Cambridge, Maryland 21613; tcarruth@ca.umces.edu

William C. Dennison, Integration and Application Network, University of Maryland Center for Environmental Science, P.O. Box 775, Cambridge, Maryland 21613; dennison@