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**P.O. Box 65
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Ecosystem Management Concepts: Connecting the Dots among the Sciences as Viewed from an Integrated Science Perspective

Robert Higgins, National Park Service, Geologic Resources Division, P.O. Box 25287, Denver, Colorado 80225-0287; bob_higgins@nps.gov
Judy Geniac, National Park Service, Natural Resource Program Center, P.O. Box 25287, Denver, Colorado 80225-0287; judy_geniac@nps.gov
Jim Wood, National Park Service, Geologic Resources Division, P.O. Box 25287, Denver, Colorado 80225-0287

Introduction

This paper summarizes a three-part topical session, "Ecosystem Management Concepts: Connecting the Dots between the Physical and Biological Sciences," which emphasized the ecosystem concept for resource management, reinforced an integrated science approach to ecosystem management, and promoted the geological science contribution to ecosystems and multidisciplinary teams. Additionally, the concept of *geodiversity,* coined from its familiar predecessor, *biodiversity,* was introduced. The sessions provided case studies of units of the national park system or examples of ecosystems issues that could apply to national parks (Figure 1). This was done to illustrate the benefits of an integrated science approach so that these methods can be incorporated into future natural resource management programs.

Figure 1. Careful monitoring of Alaskan glaciers provides critical information about the global warming dilemma. National Park Service geologist Ron Karpilo setting up to document Muldrow Glacier in Denali National Park, summer of 2004.

In addition to the twelve companion presentations that made up these sessions, nine park vignettes were provided as examples where physical sciences in general and geoscience in particular have significant consequences for ecosystem function. In some instances the examples were used to point out the significance of geology. In other instances they pointed out where geoscience was ignored in ecosystem management, an oversight that often had negative results. Other examples illustrated success stories of how the integrated science approach produced excellent results when all the disciplines were considered valuable on the multi-disciplinary team. Abstracts for the other talks can be found in the conference program and abstracts book, available at the George Wright Society website (www.georgewright.org).

Integrated science approach

Higgins' talk was titled "Integrated Science: The Importance of Understanding Other Scientific Perspectives," and was intended to set the stage for the other presentations that followed. How we manage our lands, and specifically our public lands, depends upon how we view ecosystems. John Muir once observed that when we try to pick out anything by itself, we find it hitched to everything else in the universe. Understanding how these interdependent ecological systems work provides the basis from which we attempt to manage them. If we are going to successfully implement an integrated approach, then we need to have an appreciation of the natural sciences and the social sciences, which comprise the ecosystems. It is our ability to appreciate different perspectives that will be critical to the success of multidisciplinary teams created to work through solutions to land management issues.

Lawmakers, park managers, and scientists agree that science is needed to manage parks, as evidenced by passage of the National Parks Omnibus Management Act of 1998. To address resource issues, research in the basic scientific fields is critical, but just as importantly the National Park Service needs scientists of different disciplines and perspectives (i.e., integrated science teams) to arrive at comprehensive solutions. Changes to implement these approaches are occurring, but a number of factors hinder the rate of progress in taking the ecosystem approach. Resource specialists are most comfortable operating within their area of experience and academic training, and often that expertise is limited to biology. Many parks are not accessing specialized expertise, such as that offered by geoscientists, biogeoscientists, and geoecologists. The time, effort, and cost of bringing together multidisciplinary teams have also been a deterrent. What is helping us progress? We have a broadening definition of ecology that has begun to include the abiotic, such as ocean temperature, soil chemistry, and even the texture of cliff faces. Our view of ecology is changing.

In the late 1960s, our first view of Earth from space gave us a striking image of the interdependent nature of our planet's ecosystems. Since then, there has been an increasing public expectation, nationally and internationally, that scientists would eventually gain an understanding of our global ecology and thereby improve our ability to preserve the environment in which we live. There are further expectations that national parks protect the best examples of pristine conditions and therefore may provide a baseline for ecosystem comparisons. By gathering long-term data on ecological indicators of change in our national parks, we hope to gain a better understanding of the physical components of ecosystems and provide information that will contribute to the preservation of healthy ecosystems (Higgins and Wood 2001).

The original concept of ecology and the ecosystem was a biological one. It focused on the interaction of species, such as predator–prey relationships, declining populations and causes for extinction, etc. In short, ecology was a biological concept. Landscapes began to creep into the picture primarily as the basis for habitat. Geology was thought of as the backdrop on which the complex and varied interactions were played out. It involved processes that take millions of years and was therefore not often considered in the design and implementation of land management programs. This is a basic misconception that has plagued our understanding of the role of geology in ecosystem management, and is a factor even to this day. In reality, the opposite is true: geologic processes can occur rapidly, in the same timeframe as biological processes, and are easily observed over the period of a human lifespan. Geology is a dynamic part of the physical science component of the ecosystem, which is as important as the biological and human components.

Geology and the other physical sciences, along with information from social and biological sciences, contribute important information to our understanding of ecosystem function. The triangular diagram (Figure 2) conceptually illustrates this ecosystem model.

Understanding ecosystems requires not only knowledge of the component parts and their interactions, but of their natural cycles and variability as well. In the last few decades, we have come to realize that change in an ecosystem is natural and desirable. Steady-state conditions over time are not generally found in nature. This concept is important for our understanding of the interaction of human influences and natural processes. We perceive that the human component of change in the ecosystem is expanding disproportionately and often at the expense of abiotic and other biotic components. But, measuring stress at the interface between humans and the environment requires scientific tools that can resolve naturally occurring change from human-induced change (Higgins and Wood 2001).

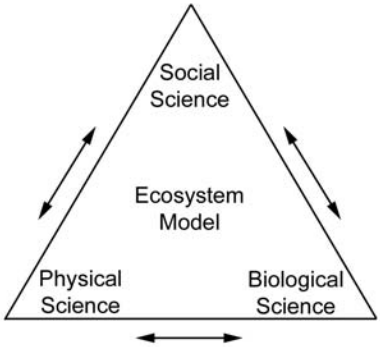


Figure 2. Illustration of how contributions of the different sciences contribute to understanding the ecosystem.

Many people develop a comfort zone in the vicinity of one of the points of the triangle model. However, we often find the solutions to our resource management issues in the area closer to the center of the triangle. This indicates the issues tend to be multifaceted, often having biologic, physical, and social aspects.

Making the point for the forgotten science

In addition to addressing the misconception of physical features as scenic backdrops to the plants and animals, there is another major concern: overcoming an entrenched bias toward one aspect of ecosystems, the biocentric approach. The intrinsic value of geology and the possible roles it plays in ecosystems are just barely being realized, despite the fact that geologic processes and features are often primary reasons for establishing many parks. Geology has often been inadequately addressed in park planning, facility design and placement, visitor safety, resource management, and visitor education. The consequence has sometimes been that park facilities are built in geohazardous areas, park visitors are exposed to geologic hazards, management decisions are detrimental to resources, and educational displays are incomplete (Shaver and Wood 2001).

Although outnumbered by more than ten-to-one by Park Service biologists, the agency's geoscientists are becoming part of an integrated approach to science-based resource management in parks (Figure 3; Shaver and Wood 2001). The hope is that, as park managers gain access to geoscientists, they gain an appreciation of the value and relevance of geology for preserving and understanding park resources.

In order to measure success, there are several things to watch over the next decade. The first is the degree to which geologic monitoring is incorporated into ecological (vital signs) monitoring programs. One of the key concepts of monitoring is to ensure that we design park programs that cover all aspects of the ecosystem so we increase our chances of detecting the first trigger of change. If geological processes are not being sufficiently monitored, we increase the possibility of missing the first element of change in a particular ecosystem. The absence of geologic monitoring data also has the potential of giving us an inaccurate picture of the ecosystem. Budgetary constraints force us to pick and choose what monitoring we can afford, and this simply magnifies the need to use multidisciplinary approaches in carefully weighing which vital signs we should choose.

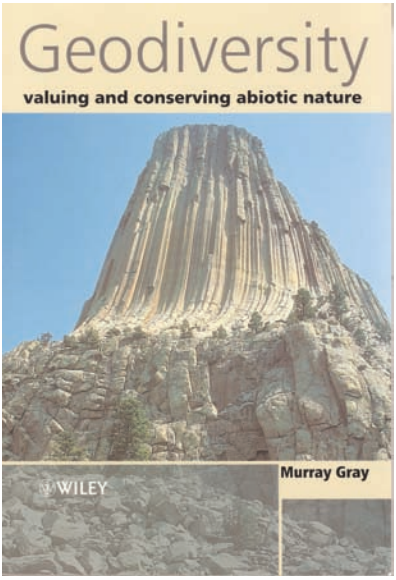
Figure 3. Characteristics of the rock, as well as coastal processes, biological communities, and human activities, all play a part in designing projects for effective resource management. Photograph taken by National Park Service geologist Rebecca Beavers at Cabrillo National Monument.

The second parameter for success is to improve on the availability of geologic information in our planning documents. Geologic information is needed to clearly frame some of the important issues of park planning. The Park Service is also embarking on an ambitious objective to create stewardship (natural resource) plans over the next five years for every park in the system. In order to have a comprehensive natural resource management plan, it is critical that geologic information be incorporated.

New concepts from the geologic community

A movement within the geologic community is giving rise to a new way of thinking about geology: it is the concept of geodiversity. The concept of geodiversity, a term coined from its familiar predecessor, biodiversity, comes alive in Murray Gray's new book, *Geodiversity: Valuing and Conserving Abiotic Nature* (Figure 4). The book uses arguments parallel to those used to support the importance of biodiversity to build a strong case for valuing geodiversity. There are three significant concepts and parallels. One is the need to identify the geologic resources, such as features and processes, that are analogous to biotic species inventories. Another is embracing an understanding and definition of geologic values that is parallel to the values we have placed on maintaining diversity of biota. The third is realizing that the protection of geologic features and processes is equivalent in importance to preventing species extinction and disruption of migrations (Gray 2004).

Figure 4. In his 2004 book *Geodiversity: Valuing and Conserving Abiotic Nature,* Murray Gray makes the point that preservation of important geoheritage sites is just as critical as preservation of biological habitat and communities.



Although there are a number of national, state, and local programs focused on creating inventories of geologic features, they do not use the same criteria and are not compatible with one another. The National Natural Landmarks program is the best documented effort designed to identify and document nationally and regionally significant landmarks. Examples of geologic heritage sites include Grants Lava Flow, John Day Fossil Beds, Malaspina Glacier, and Eureka Sand Dunes. Parks are now required to produce a paleontological inventory, which could provide another type of data. We have created many other pseudo-inventories by simply identifying significant sites, such as citing geologic type sections in scientific literature; setting aside parks that focus on geologic icons (Devils Tower, Yellowstone, Grand Canyon), setting aside areas that have scientific significance (Hagerman Fossil Beds, Wind Cave, Hawaii Volcanoes), and writing curricula and trail guides to natural curiosities (Bubble Rock in Acadia, cross-bedded sandstones in Zion, and karst in Everglades).

Because of the durable nature of rocks and their seemingly endless supply on the landscape, it may be surprising to learn that many geologic features are as rare as endangered species. Fossils created millions of years ago, dazzling cave features, or rare minerals can never be replaced when destroyed by the hands of vandals and collectors. Like the strategies to protect against biological extinction, parks must work to make the public aware that a similar permanent loss can happen to our rare geologic features and fossils. For the most part, geologic resources are irreplaceable and, in some cases, even minor disturbance can result in the loss of significant scientific information. We owe a debt of gratitude to Murray Gray and the geologic community for creating a heightened awareness that geology, like biology, has a rich diversity worth identifying, valuing, and protecting.

Advances in geotechnology are adding to park's traditional field observation and investigation methods. The technological tools now available are more precise and have wider application to support our integrated science approach. Such tools range from the macro- to the micro-scale. Remote sensing has been available for decades; however, the continuing improvements in resolution and different wavelength scanning capabilities are enhancing our ability to examine both geologic features and biota in greater detail. By using geologic themes with biotic layers, GIS capabilities are expanding our ability to spot geospatial relationships. Most recently developed, terrestrial three-dimensional laser scanning makes it possible to capture critical landscape data on plants, geology, and impacts from social activities at one time. It is also looking very promising to use this technology as a monitoring tool, when used at repeated intervals. The ability to apply such technologies in a multidisciplinary approach may lead to the availability of better information to guide management decision-making.

The geologic community itself is becoming more integrated in the disciplines that it encompasses. New broad-based curricula are being developed, and academic degrees are now based on integrated science courses whose names reflect this integration: biogeoscience, geoecology, and geoarchaeology. Additionally, the traditional ecology degrees are beginning to require a heavy dose of physical sciences and social sciences. Even professional organizations in geology now recognize the importance of crosscutting work and offer opportunities for recognition of multidisciplinary endeavors by scientists. All of this could benefit parks by providing a community of scientists who could provide support to our integrated science approach.

Conclusion

While there may be some consternation in the geologic community, there is reason to be guardedly optimistic that we are making progress in the right direction. Paradigm shift often occurs as an evolving process, rather than an abrupt change. The Park Service is slowly moving away from a stovepipe approach to science, where options are developed by a single specialist or a group of like-minded specialists. We are undergoing a slow, but steady, change to an integrated science workforce.

The National Park Service has made a strong commitment to science-based management and has taken several steps toward gathering and using natural resource information to gain a better understanding of park resources. The triangle ecosystem model is a means to illustrate how information from the many scientific disciplines within the physical, biological, and social sciences can be integrated into a holistic ecosystem management approach. The concept of biodiversity and the emerging concept of geodiversity provide perspectives on the interplay between physical settings and biological communities. Examples of integrated science information being applied to park management issues make the point that the integrated science approach can work. We must be ever-vigilant of our need to examine scientific information from many disciplines in order to guide our management decisions and realize our goals for ecosystem management.

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