Using Integrated Research and Interdisciplinary Science: Potential Benefits and Challenges to Managers of Parks and Protected Areas

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Introduction

Our purpose in this paper is to build a case for utilizing interdisciplinary science to enhance the management of parks and protected areas. We suggest that interdisciplinary science is necessary for dealing with the complex issues of contemporary resource management, and that using the best available integrated scientific information be embraced and supported at all levels of agencies that manage parks and protected areas. It will take the commitment of park managers, scientists, and agency leaders to achieve the goal of implementing the results of interdisciplinary science into park management.

Although such calls go back at least several decades, today interdisciplinary science is sporadically being promoted as necessary for supporting effective protected area management (e.g., Machlis et al. 1981; Kelleher and Kenchington 1991). Despite this history, rarely has "interdisciplinary science" been defined, its importance explained, or guidance provided on how to translate and then implement the associated research results into management actions (Tress et al. 2006; Margles et al. 2010). With the extremely complex issues that now confront protected areas (e.g., climate change influences, extinctions and loss of biodiversity, human and wildlife demographic changes, and unprecedented human population growth) information from more than one scientific discipline will need to be brought to bear in order to achieve sustained management solutions that resonate with stakeholders (Ostrom 2009). Although interdisciplinary science is not the solution to all problems, we argue that interdisciplinary research is an evolving and widely supported best practice. In the case of park and protected area management, interdisciplinary science is being driven by the increasing recognition of the complexity and interconnectedness of human and natural systems, and the notion that addressing many problems can be more rapidly advanced through interdisciplinary study and analysis.

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Protected area managers have experienced a recent move toward interdisciplinary science, both from within and outside their organizations (e.g., Myers et al. 2007), and with considerable encouragement from the scientific community (e.g., NAS 2004). Also, a proper implementation of the International Union for the Conservation of Nature's protected area categories (Dudley 2008) requires integrated approaches. Whereas parks and protected areas worldwide have traditionally been largely managed from a natural resource-based perspective, the recognition of socioeconomic connections between parks and people, or the questions of governance and management effectiveness, require more complex interdisciplinary scientific research. Managers recognize that such studies are cumbersome to oversee, the results are often difficult to translate into on-the-ground actions, and both conceptually and financially can be impeded by a lack of support. Recognizing these challenges, in this paper we further define interdisciplinary science, discuss its application to park and protected area management, and then examine potential barriers to success. We then close by offering ways of organizing, implementing, and strengthening interdisciplinary science to confront the important issues facing parks and protected areas in the 21st century.

Defining interdisciplinary science

Interdisciplinary science is founded upon the expectation that much of the most important scientific findings of the future will come from research that spans two or more disciplines. To understand what is meant by interdisciplinary science and why it is so important to parks and protected area management, we will first provide definitions, and then the context in which interdisciplinary science is best practiced. Following are definitions from a 1998 joint meeting of the US Geological Survey and Ecological Society of America that explored integrated science (see http://www.esa.org/science_resources/programs/past_projects.php).

- **Disciplinary science** may be characterized by singular efforts within a well-defined specialization. The goal of disciplinary science is a deep understanding of a single problem or a single aspect of a problem. Although a disciplinary effort may involve many scientists, and the scope of the analysis may be broad, it will still employ the methods and theories of a single discipline.
- **Multidisciplinary science** is an additive approach that combines the efforts of more than one discipline. Multidisciplinary efforts seek to combine the results of specialized, disciplinary approaches for a broader understanding of a problem or question. Cooperation among contributors is necessary.
- **Interdisciplinary science** is an integrated approach that synthesizes the perspectives of multiple individual disciplines during all phases of the research to investigate and answer a question, or solve a problem. It differs from multidisciplinary science in that integration is required from its genesis. Because of the complexity of the issues that interdisciplinary research seeks to solve, often new questions emerge as the problem is further defined and approaches adapted to changing conditions and by systematic trial and error. Consequently, the results of interdisciplinary efforts may be emergent as well. Ultimately true collaboration, beyond mere cooperation, is essential for successful interdisciplinary science.

The distinction between multidisciplinary and interdisciplinary science can be further refined by stressing the fact that a multidisciplinary approach focuses on breaking down a problem into unidisciplinary segments, which are solved individually. Interdisciplinary approaches on the other hand, refrain from making this breakdown but rather stress the above-mentioned cooperative approach (Kelleher and Kenchington 1991: 28). Others, such as Tress et al. (2006) and Gray (2008), suggest defining the transfer of research to managers as "transdisciplinary," but in this paper we choose to utilize the term "interdisciplinary." We believe that interdisciplinary research should also include the transfer of scientific knowledge into management practice of parks and protected areas. Table 1 provides a description of many of the characteristics of interdisciplinary approaches to research.

Application of interdisciplinary science for parks and protected areas

Today, the health and functioning of protected areas and surrounding landscapes are threatened by a range of human activities (threats and drivers of change) and resulting impacts such as deforestation, habitat fragmentation, overfishing, a growing disparity in human wealth, and civil unrest (Daily and Ehrlich 1999; Hassan et al. 2005). Many of these changes span terrestrial and aquatic systems as well as local, regional, and transboundary spatial scales, although the actual impact of the threats might vary by geographical region. Successful application of interdisciplinary science maintains flexibility for adaptive changes at multiple scales, while still embracing the complexities of human–environment interactions (Gunderson and Holling 2001). Understanding and addressing these global trends will not fall within the exclusive domain of one scientific discipline. As noted by Steffen et al. (2005), the impact of humankind has emerged as a globally important force that is capable of reshaping the face of the planet:

- Humans have already transformed 40–50% of the ice-free land surface on earth.
- Humans now use 54% of the readily available fresh water on the globe.
- Humans are now an order of magnitude more important at moving sediment than the sum of all other natural processes operating on the surface of the planet.
- Humans now fix more atmospheric nitrogen than all terrestrial sources combined.

Table 1. Characteristics of interdisciplinary approaches to research.

• Recognize the interdependence of science and societal concerns
• Value all disciplines (social and natural) and honor the validity of each other's work
• Use approaches to understand the complexity of interlinked natural and social systems
• Illuminate the complexity and interdependence of our biosphere as a coupled natural and social system
• Develop rigor and breadth from the strengths of the participating disciplines
• Provide an adaptable approach in which teams are organized explicitly to address scientific questions and/or societal concerns, and which allows members to feel free to move on and off teams when appropriate
• Share common vision, authority, responsibility, accountability, trust, and ownership of the endeavor
• Communicate knowledge and understanding to society in a relevant, timely, and readily accessible manner (translational)

The complexity of our earth system demands new and innovative problem-solving approaches. E.O. Wilson, one of the world's most prominent biologists, summarized the situation in this way: "We are drowning in information, while starving for wisdom. The world will henceforth be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely" (Wilson 1998: v). In conclusion, interdisciplinary science is important because there are many crucial links among research disciplines that can more effectively meld the wide array of scientific knowledge that is needed to effectively address complex park management issues. For interdisciplinary science to prosper in the future, it will need to be clearly demonstrated how science can address protected area priorities using tools and integrated approaches that provide answers for decision-makers to answer highly complex, coupled natural and social problems.

Barriers to interdisciplinary science in parks and protected areas

The problems faced by managers of parks and protected areas (from wildlife management issues through visitor use patterns, to potential impacts of outside development) typically require the integration of information from many disciplines. Yet there is a strongly held perception that significant barriers exist in conducting interdisciplinary science, what Machlis et al. (in press) describe as the "standard litany of difficulty." Many of these perceived barriers are relevant to interdisciplinary science in parks and protected areas, and we will discuss them in turn.

First, there are *disciplinary* barriers, which include the challenge of competing and conflicting use of scientific terms and merging scientific paradigms (e.g., biological and social evolution). Underlying this difference are powerfully held assumptions about natural and human systems; this lack of mutual understanding can often lead to a lack of mutual respect among scientists and thus impede a commitment to interdisciplinary practice. The potential for "disciplinary distrust" (often phrased as "soft versus hard science") interfering with interpersonal communications within interdisciplinary research teams is too often realized (e.g., Naimen 1999; Wear 1999; Bracken and Oughten 2006).

Second, there are *institutional* difficulties of organization and logistics. These include the effort required to assemble an interdisciplinary program or project team, the time demands for learning the rudiments of partner disciplines, and the commitment required to develop collective understanding and willingness to synthesize new ideas, concepts, theories, methods, data, and conclusions (e.g., Campbell 2005). Within the academic community, the doctoral system at research universities encourages specialization in "disciplinary stovepipes" (e.g., Golde and Gallagher 1999); even the spatial separation of potential collaborators within the same university, college, or office building can act as a barrier to good interdisciplinary practice. In park management organizations (such as the US National Park Service), the institutional separation of biophysical, social, and cultural sciences, and scientific staff and managers varies widely and can (if not managed well) act as an impediment to effective practice. Funding for interdisciplinary research is also a challenge because the research is often expensive, risky, and may require a long-time horizon.

A third barrier is the perception that interdisciplinary research is "*methodologically* challenged." In particular, the lack of existing (and robust) conceptual frameworks means that theorizing and hypothesis-making is often separated from a clear and articulate interdisciplinary framework (e.g., Kinzig 2001). Similarly, the lack of a common set of protocols, procedures, and research techniques makes methodologically rigorous interdisciplinary work even more difficult.

Finally, the challenge can impact *individual* scientists. The high personal investment needed to master interdisciplinary science, the long time horizon of many interdisciplinary projects, the difficulty of acquiring funding, and the career recognition system (skewed to publishing research results within disciplinary journals) all conspire to add to the litany of difficulty.

Overcoming barriers to interdisciplinary research

Many of the *disciplinary* and *institutional* barriers that we have presented are presently being overcome through increased recognition regarding the value of interdisciplinary research, coupled with improved science training and education (Fitzgerald and Stronza 2009). US research organizations such as the National Science Foundation (NSF) and private foundations such as Templeton, Heinz, and Doris Duke have developed programs that are focused on funding interdisciplinary research and developing new models for graduate research (NSF 2011). To facilitate interdisciplinary research, universities are developing new departments, graduate programs, and institutes organized around grand challenges, such as the School of Sustainability at Arizona State University (see Crow 2010), Integrative Graduate Education and Research Traineeship (IGERT) programs, the Institute for Parks at Clemson University (www.clemson.edu/hehd/departments/prtm/centers-institutes/institute_for_parks.html/), and, within the US government, with the US Geological Survey's John Wesley Powell Center for Analysis and Synthesis (http://powellcenter.usgs.gov/), and many others. These activities facilitate the formation of interdisciplinary teams that are ready to work together to address emerging issues. By increasing the support and training in interdisciplinary research, individuals are emerging from graduate school more prepared to collaborate on interdisciplinary research (e.g., Kinzig 2001). Similarly, many national parks and protected areas have onsite research scientists who can serve as the catalyst for interdisciplinary science by identifying information needs, organizing interdisciplinary teams, and providing critical logistical support. Federal science agencies, such as the US Geological Survey, can also foster interdisciplinary science because of the large number of discipline specialists available to form collaborative groups.

Financial resources will continue to be a challenge. If park and protected area managers are going to use the best available science to inform management decisions, then partnerships and collaborative funding opportunities must be pursued. Increasingly, US federal agencies are partnering with university researchers to pursue external funds, such as through NSF, to support important interdisciplinary research. An example is NSF's Coupled Human/Natural Systems research competition (NSF 2010). Periodically, emerging national issues garner the attention of lawmakers and significant funding and new programs are created to address those needs. In some cases, this expansion of opportunity for interdisciplinary science extends to parks and protected areas. For example, in 1998 Congress enacted the National Parks Omnibus Management Act. This increased funding to the US National

Park Service budget, and the appropriations bill in Section 202 set forth a research mandate for the secretary of the interior to provide for the highest-quality science and its use in decision-making. Other examples include responses to natural and industrial hazards, risk communication, and most recently, climate change. In 2010, many of the US Department of the Interior land management agencies received significant funding increases for global climate change activities. In Europe, the European Union (EU) took action to support more integrated, interdisciplinary science approaches as early as 1998, when the 5th Framework Programme, the main EU science-funding scheme for the 1998 to 2004 period, was launched. Although evaluations showed that in the end, only a minority of funded projects were truly interdisciplinary, this prepared scientists for future interdisciplinary research (Bruce et al. 2004). Although not exclusively addressing park and protected area issues, the German federal government implemented in 1999 a special funding scheme called "socio-ecological research," through which interdisciplinary research groups are encouraged to work on global challenges such as climate change and biodiversity loss. Still, too few of such research programs exist to satisfy the increasing demand for integrated research approaches.

At the *individual* level, researchers are ignoring or overcoming the disincentives in conducting interdisciplinary research, largely through their passion and motivation to solve problems and protect our natural and cultural resources. This is coupled with institutional, organizational, and structural changes, which are now promoting and rewarding interdisciplinary research. An example is the emergence of several important and prestigious journals (e.g., *AMBIO, Conservation Biology, Environmental Conservation, BioScience,* etc.) to recognize and publish interdisciplinary research.

At the *methodological* level, many of the barriers have been eliminated or minimized through the development of a range of theoretical frameworks such as the human–ecosystem model (e.g., Machlis et al. 1997), resilience and sustainability (e.g., Folke et al. 2002), and other systems-type approaches coupled with computational and software advances. Examples of the latter are the increased sophistication of geographical information systems (GIS) software and statistical packages. The upshot of these changes is that we are seeing increasingly successful and more sophisticated interdisciplinary research that is seeking to find solutions to ever-more complex issues facing humankind.

Examples of interdisciplinary research in parks and protected areas

One example of interdisciplinary research in parks and protected areas was a project that drew on conceptual frameworks from the social and natural sciences and was carried out in the northeastern US. (Monz et al. 2010; van Riper et al. 2011). This research determined the tradeoffs that park visitors were willing to make among environmental conditions, recreation use levels, and development at three mountain summits that each had varying biophysical conditions and a range of recreational opportunities. The findings suggested that visitors held different preferences for resource impacts, the number of encounters with other visitors, and intensity of management.

Another example is an interdisciplinary project that predicted river flows in Yosemite National Park, and involved scientists with expertise in biology, sociology, geology, hydrology, climatology, and geography. The onsite biologist had extensive knowledge about the vegetation, fire history, and visitation of the park, hydrologists contributed detailed synthesis of stream flow data, geographers provided digital topographic data, geologists had information of surface and subsurface geologic formations, and climatologists integrated climate data with all of the other information to develop a predictive model of watershed dynamics. The model that resulted from the interdisciplinary project will enable park managers to anticipate annual river flows as well as flood events, and their social and ecological implications.

A third example of interdisciplinary research is an effort along the Mexico–US border that examined environmental health within the Santa Cruz watershed (Norman et al. 2010; 2011). Given the scarcity of water resources in the desert Southwest, scientists identified risks to surface water, and the potential consequences to riparian ecosystems and, ultimately, human health. Using an interdisciplinary and integrative approach, social scientists, geographers, hydrologists, biologists, and geologists worked together to track organic and inorganic contaminants and sediment transport. Samples were taken at five protected areas in Mexico and the US, in an effort to identify contaminant levels in stream sediment, aquatic macroinvertebrates, aquatic plants (macrophytes), algae, riparian grasses, fish, and birds. The study identified contributing areas, sources, and transport modes of contaminants and tracked contaminant movement in surface waters, providing an improved understanding of the effects of human activities on aquifer dynamics and contaminant transport, and enabled the development of a model to identify where implementing management practices to abate pollution could be most effective.

The above examples are only a few of the many interdisciplinary projects now being conducted in parks and protected areas throughout the world. We use these three projects only as examples of those that combine various science disciplines such as social, biological, and physical science to ask what consequence management has for visitor experiences and perceptions, and on traditional ecological knowledge. These examples also demonstrate how research can successfully span across disciplinary divides to provide more comprehensive recommendations for managers of parks and protected areas.

Ways forward: Increasing use of interdisciplinary science

In an effort to further advance the use of interdisciplinary science and to improve park and protected area management, we are suggesting the following:

Develop and integrate research teams that can address complex, interdisciplinary societal priorities pertaining to parks and protected areas. The nature of societal issues, such as those identified by Myers et al. (2007), is such that multidisciplinary information—economic, technological, social, political, and ecological, and their interdisciplinary synthesis—will be needed by decision-makers as they seek effective solutions. The broad array of scientific expertise within universities, the US Geological Survey, and other science organizations, coupled with the strong resources management and field-based scientific expertise within the US National Park Service, US Bureau of Land Management, US Fish and Wildlife Service, and other land management agencies, makes for an ideal situation to provide the scientific information needed to inform future management actions. While each agency has disciplinary strengths, the future requires that these public institutions find ways to integrate them. Together, as a whole, we can provide a service to park management that is greater than the sum of our parts.

Demonstrate the ability to conduct successful large-scale interdisciplinary science efforts that address priority issues facing parks. Protected area managers, policy-makers, and legislators need to be convinced of the benefits of large-scale, complex, interdisciplinary research, along with the challenges that type of endeavor entails. It is only after having demonstrated an ability to provide a foundation of strong disciplinary science within a large-scale (e.g., national or regional) multidisciplinary framework, can this effort move forward. Moreover, projects will require strong execution, tangible outcomes, and timely integrated information that support decision-making. With these demonstrated successes, interdisciplinary science will be more likely embraced by managers of parks and protected areas, and society.

Inform and educate decision-makers, policy-makers, and park and protected area managers about the benefits of interdisciplinary science. Ongoing communication among park and protected area managers, scientists, and decision-makers about the complexity of threats, and the utility of interdisciplinary science to identify potential causes and solutions, can provide new and useful scientific products and services to managers and decision-makers to meet those threats. Likewise, broadening a partner base that focuses on interdisciplinary science and that also seeks every opportunity to make the public more aware of the benefits of this approach for answering complex scientific questions may also result in similar outcomes. Finally, improving scientific literacy, and explaining the utility and importance of interdisciplinary research as a part of leadership training programs, may ensure that future resource managers and decision-makers consider this approach when facing resource threats and determining how to manage them.

Conclusion

Interdisciplinary and integrated information coming from economic, technological, social, political, and ecological arenas will be needed by all park and protected area managers as they seek effective solutions to today's complex issues. As issues such as global climate change and sustainable energy struggle to capture the attention of legislators, park and protected area managers working in concert with scientists need to be prepared with a clear and compelling multi-year research agenda for interdisciplinary science. This must include a demonstrated track record of performance, as well as a clearly identified team of scientists and managers that has the ability to work across disciplines and to quickly respond to emerging threats and issues. Otherwise, new programs and increases in funding will likely not go toward solving emergent problems in parks and protected areas.

Park managers need to address topics such as resource adaptation to climate change over a large protected landscape, pinpointing linkages between the environment and human use patterns while also clarifying the meaning of ecosystem health and restoration. To address these issues within the core research capabilities of a diverse cross-section of private, state, and federal research communities, scientists will be communicating with park and protected area managers that oversee lands that can be used as benchmarks and controls from which to assess human-induced changes to the environment. For many of these important societal priorities, “the train has already left the station.” For example, while the global community is struggling to develop meaningful policies that will help mitigate and adapt to climate change, it must also come to terms with:

- The 2011 unrest in the Middle East,
- The rising cost of crude oil, which is moving back over $100 per barrel, forcing and gasoline prices upward,
- Continued increase of the human population and changing demographics,
- Further changes in land use practices; and
- Instability in the price of key commodities, such as the recent price spike for corn under expectations of future increases in ethanol production to fulfill sustainable energy goals.

All this is taking place while little is known about the impacts on water availability, ecosystems, and species.

Only by recognizing that we are in a rapidly changing environment, and embracing and encouraging interdisciplinary science, can park and protected area managers receive the information necessary to best manage the world’s most valuable natural resources. The future requires that we find ways to better integrate the findings of interdisciplinary research into park management. Together, scientists and land managers can provide a service that is greater than the sum of the parts, and create an identity of leadership and program growth that addresses large-scale societal needs within parks and protected areas of the world.

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