ENVIRONMENTAL LAW INSTITUTE

Lasting Landscapes: Reflections on the Role of Conservation Science in Land Use Planning

"Healing the land must begin with good planning, for there are so many ways we can go wrong—or at least waste time and money—if we do not proceed intelligently and on the basis of the best available information."

Reed F. Noss

ENVIRONMENTAL LAW • INSTITUTE®

Lasting Landscapes: Reflections on the Role of Conservation Science in Land Use Planning

The Environmental Law Institute®

Acknowledgements

This publication is a project of the Environmental Law Institute's State Biodiversity Program. Funding for this report was provided by the Surdna Foundation, George Gund Foundation, Henry M. Jackson Foundation and a contribution from an individual donor. Senior editors of this report are Rebecca Kihslinger and Jessica Wilkinson. Jim McElfish provided valuable guidance and review. Jay Austin provided editorial assistance.

Related Research Reports from ELI

From ELI's Biodiversity and Land Use Planning Program

Conservation Thresholds for Land Use Planners

Nature-Friendly Ordinances: Local Measures to Protect Biodiversity

Planning for Biodiversity: Authorities in State Land Use Laws

Ten Things Wrong with Sprawl

About ELI Publications-

ELI publishes Research Reports and briefs that present the analysis and conclusions of the policy studies ELI undertakes to improve environmental law and policy. In addition, ELI publishes several journals and reporters-including the Environmental Law Reporter, The Environmental Forum, and the National Wetlands Newsletter-and books, that contribute to education of the profession and disseminate diverse points of view and opinions to stimulate a robust and creative exchange of ideas. Those publications, which express opinions of the authors and not necessarily those of the Institute, its Board of Directors, or funding organizations, exemplify ELI's commitment to dialogue with all sectors. ELI welcomes suggestions for article and book topics and encourages the submission of draft manuscripts and book proposals.

Lasting Landscapes:
Reflections on the Role of Conservation Science in Land Use Planning

ISBN 978-1-58576-113-3-5, ELI Project Code 042804

An electronic retrievable copy (PDF file) of this report may be obtained for no cost from the Environmental Law Institute website www.elistore.org

Table of Contents

Introduction

As of last count, the number of plant and animal species listed as either threatened or endangered under the U.S. Endangered Species Act has topped 1,300.[1] For the vast majority of these species – almost 85 percent – habitat loss and fragmentation are the major causes of their imperilment as well as the most significant threats to their conservation. There is no doubt that the number of imperiled species will continue to grow as more habitat is converted for, and fragmented by, human development and use. Moreover, across North America, even many non-imperiled species are finding their habitats impaired, their ranges diminished, and their numbers in retreat. The time to act is now…*before* additional species populations begin to decline precipitously.

Land use and development decisions made at the local, county, and state levels have a significant and cumulative effect on the conservation of native species diversity. Through their planning and local regulatory powers, land use planners and local elected officials have the ability to influence the types, extent, and arrangement of land uses across the landscape. These patterns can have a profound influence on the viability of biodiversity far beyond municipal boundaries.

Conservation biologists have made considerable progress over the past 20 years in determining how the size, shape, and connectedness of habitat affect the sustainability of species. In an effort to make this information readily available to those who make the critical decisions about how land is used and managed, the Environmental Law Institute published *Conservation Thresholds for Land Use Planners* (2003). That report draws on the scientific conservation literature to provide concrete targets for planners to use when making decisions about how much land to protect, the adequate size and location of habitat corridors, widths for riparian buffers, and maximum distances supportable between separate habitat patches. These conservation thresholds have been used extensively across the country to support land use, open space, and smart growth plans that maintain quality natural habitat in the amounts and patterns necessary to ensure sustainable, viable populations of native species.

In 2006 and 2007, ELI turned to nine of the leading thinkers in the land use planning, conservation biology, and conservation policy professions to explore how the field of conservation planning could be further advanced. Each was asked to reflect upon the role of his/her respective profession in promoting the use of science-based information in land use planning.

These thought-provoking essays, introduced by Dr. Reed Noss, make it clear that a more intentional approach to conservation planning is needed. However, currently conservation planning is "mired in an implementation crisis"[2] and the barriers to incorporating science into planning remain formidable. As Dr. Noss observes, to date, most conservation planning successes have been the result of "an auspicious combination of high-quality information, visionary leadership, a linkage between and translation of science and planning, and solid funding," often jump-started by a regulatory planning requirement. This report is a first step in making these auspicious convergences more commonplace, proactive, and carried out at a landscape scale.

Eight of these leading thinkers – Philip Berke, Ph.D., Arlan Colton (FAICP), Sherry Ruther, Timothy Duane, Ph.D., Adina Merenlender, Ph.D., Dan Perlman, Ph.D., Bruce Stein, Ph.D., and David Theobald, Ph.D. – were asked to reflect upon the opportunities for and barriers to advancing the integration of biodiversity conservation and land use planning. Dr. Reed Noss provides a synthesis and commentary on the collected essays. Although each author brings a unique perspective backed by years of experience in separate disciplines (see Authors' Biographies), six general recommendations emerge for how to advance conservation planning and the application of conservation thresholds:

1. U.S. Fish and Wildlife Service Summary of Listed Species at http://ecos.fws.gov/tess_public/Boxscore.do

2. Knight, Andrew T., Richard M. Cowling, and Bruce M. Campbell. 2006. "An Operational Model for Implementing Conservation Action." *Conservation Biology*. 20(2): 408-419.

- Develop *communications* tools for land use planners to communicate the value of conservation planning to decision-makers such as local governments, and for scientists to communicate the knowledge that will enable decision-makers to carry out effective conservation.
- Develop *requirements and incentives* for proactive conservation planning.
- Develop tools to *measure the effectiveness* of conservation planning, and provide for adaptive management where needed to achieve the intended outcomes.
- Develop requirements and incentives to enable public and private decision-makers to *overcome the disconnect between the different scales* at which land use planning and regulation, and effective planning for conservation of biodiversity are carried out.
- To the extent possible, *tailor conservation thresholds* for each specific situation, relying upon scientific expertise and the best available information.
- Develop outreach programs to provide planners with access to a robust *technical support infrastructure,* and provide *interdisciplinary training* for planners and conservation scientists.

We hope that the recommendations outlined in the following essays will promote the application of conservation thresholds, advance conservation planning, and provide valuable insights into how you can contribute to maintaining lasting landscapes.

Rebecca Kihslinger
Jessica Wilkinson

The Environmental Law Institute

Authors' Biographies

Philip R. Berke, Ph.D.

University of North Carolina

Philip R. Berke is a Professor in the University of North Carolina's Department of City and Regional Planning. He also serves as Chair of the Environment Studies Curriculum of the Carolina Environmental Program and Professor in the Curriculum of Ecology.

The central focus of his research is to develop a deeper understanding of the connections between human settlements and the natural environment. His research seeks to explore the causes of land use decisions, how these decisions impact natural systems, and the consequences of these impacts on human settlements. His ultimate goal is to seek solutions to complex urban development problems that help communities live within the limits of natural systems.

Since 1990, Dr. Berke has presented seminars at 10 universities throughout the United States, and lectured internationally. He is currently a Collaborative Research Scholar of the International Global Change Institute in New Zealand. Dr. Berke has been a member of the National Research Council's Committee on Disaster Research and the Social Sciences since 2003 and between 1995 and 2002 he was a Faculty Fellow at the Lincoln Institute of Land Policy. In 1993, he was a Senior Fulbright Scholar at the Centre for Environmental and Resource Studies, University of Waikato, New Zealand. Dr. Berke has also served as a consultant on land use and environmental planning to state and local governments. He currently serves on the editorial boards of the Journal of the American Planning Association and Journal of Architecture and Planning Research.

URL:
http://www.planning.unc.edu/facstaff/faculty/berke.htm

Arlan Colton, FAICP

Pima County, Arizona

Arlan M. Colton, FAICP, is the Pima County Planning Official. He serves as Co-Chair of the Governor's Growing Smarter Oversight Council. He previously has held planning positions in both the public and private sector including serving on the City of Tucson Planning Commission. Mr. Colton holds a master's in urban planning from the University of Arizona.

Timothy P. Duane, J.D, Ph.D.

University of California, Berkeley

Timothy P. Duane is an Associate Professor in the University of California, Berkeley's Department of Landscape Architecture and Environmental Planning. He is a leading expert on land use and ecosystem management in the West.

Dr. Duane's publications include Shaping the Sierra: Nature, Culture, and Conflict in the Changing West (University of California Press, 1999), "Community Participation in Ecosystem Management" in Ecology Law Quarterly (1997) and "Regulation's Rationale: Learning from the California Energy Crisis" in the Yale Journal on Regulation (2002). Dr. Duane served as a special consultant to the Sierra Nevada Ecosystem Project in 1993-1996, was appointed by the U.S. Secretary of Agriculture to the California Spotted Owl Federal Advisory Committee in 1997, and is now working on a new book tentatively titled Wolves, Water, and Wilderness: Ecosystem Management in the Changing West. His other recent projects include an external evaluation of the Packard Foundation's $291-million Conserving California Landscapes Initiative and a project to maximize the public benefits of agricultural conservation easements.

Dr. Duane holds a J.D. from Boalt Hall School of Law at the University of California and received his Ph.D. and M.S. degrees from Stanford University in civil and environmental engineering.

URL: http://www-dcrp.ced.berkeley.edu/facbios/DuaneCV.htm

Adina Merenlender, Ph.D.

University of California, Berkeley

Adina Merenlender is an Adjunct Associate Professor in the Environmental Science, Policy and Management Department at the University of California, Berkeley.

Dr. Merenlender's primary focus is in the field of conservation biology. She is interested in the forces that influence loss of biodiversity at all hierarchical levels. Her experience spans from single species management to measures of ecosystem health to, most recently, regional land use planning. Dr. Merenlender's current research covers a diverse suite of projects that involve mapping, monitoring, and modeling natural resources and human land-use patterns. Her approach relies on integrating spatially explicit land use change models with environmental data to ultimately provide decision-support tools.

Dr. Merenlender has developed a spatially explicit interactive decision-making tool for Sonoma County open space planners to identify properties that contain natural and agricultural assets that should be prioritized for acquisition based on the relative threat and cost of each land parcel. This plan received an award from the American Planning Association and was presented at the Land Trust Alliance's annual Rally as a model for interactive decision-support tools. She also leads an interdisciplinary research team focused on sustainable water use in Mediterranean-climate watersheds that has received support from NSF and EPA. In addition, Dr. Merenlender and colleagues recently completed *Corridor Ecology: The Science and Practice of Connectivity for Biodiversity Conservation.* This book brings together data and information from a wide range of sources and distills that research into guiding principles that can help professionals successfully design and implement corridor projects.

URL:
http://ecnr.berkeley.edu/facPage/dispFP.php?I=546

Reed F. Noss, Ph.D.

University of Central Florida

Reed F. Noss is the Davis-Shine Professor of Conservation Biology at the University of Central Florida and an international consultant and lecturer. He has also worked as an ecologist for the Ohio Department of Natural Resources, Florida Natural Areas Inventory, and U.S. Environmental Protection Agency during his 35 years in the environmental field.

Dr. Noss is the author of nearly 250 scientific and semi-technical articles and several books. He was Editor-in-Chief of Conservation Biology, the leading journal in the field, from 1993 through 1997, is Past President of the Society for Conservation Biology (1999-2001), and is currently President of the North American Section of the Society. From 1993 through 1996 he held a Pew Scholars Fellowship in Conservation and the Environment. In 1995, he won the Edward T. LaRoe III Memorial Award of the Society for Conservation Biology. He is certified as a Senior Ecologist by the Ecological Society of America and is an elected Fellow of the American Association for the Advancement of Science. Dr. Noss serves on many boards, committees, and advisory panels, including the Board of Governors of the Society for Conservation Biology and (until recently) the Board of Trustees of the Florida Chapter of The Nature Conservancy. He has been appointed by Florida Governor Jeb Bush to the Acquisition and Restoration Council, which makes recommendations to the governor and cabinet on state land acquisitions and management, for a five-year term (2006-2011). His present research involves the application of science to conservation planning at regional to global scales.

Dr. Noss has a Ph.D. in Wildlife Ecology from the University of Florida, a M.S. in Ecology from the University of Tennessee, and a B.S. in Education from the University of Dayton.

URL: http://biology.cos.ucf.edu/faculty_noss.php

Dan L. Perlman, Ph.D.

Brandeis University

Dan L. Perlman is an Associate Professor of Biology at Brandeis University, where he is Chair of the Environmental Studies Program.

Dr. Perlman has co-authored three textbooks on conservation biology and ecology: *Practical Ecology for Planners, Developers, and Citizens* (with Jeffrey C. Milder); *Conserving Earth's Biodiversity* (an interactive CD-ROM created with Edward O. Wilson); and *Biodiversity: Exploring Values and Priorities in Conservation* (with Glenn Adelson). In addition, he recently launched EcoLibrary, a Web site from which he freely distributes teaching materials he has developed for ecology and environmental studies. He has been awarded university-wide teaching awards at Brandeis University (the Student Union Teaching Award twice and the Louis Dembitz Brandeis Prize for Excellence in Teaching once) and at Harvard University (the Phi Beta Kappa Prize for Excellence in Teaching), where he taught conservation biology part-time for nine years.

Dr. Perlman received a Ph.D. from Harvard University's Department of Organismic and Evolutionary Biology.

URL: http://www.bio.brandeis.edu/faculty01/perlman.html; www.EcoLibrary.org

Sherry A. Ruther

Pima County, Arizona

Sherry Ruther is the Environmental Planning Manager for Pima County, Arizona, a position she has held for four years. Ms. Ruther previously worked for 10 years with the Arizona Game & Fish Department. As a professional wildlife biologist, Ms. Ruther provides guidance to County staff and elected officials on integrating natural resource conservation into land use planning. Pursuant to the County's implementation of the Sonoran Desert Conservation Plan, she is leading the development of policy and procedures that will ensure that private development in Pima County occurs in an environmentally-sensitive fashion.

Bruce A. Stein, Ph.D.

NatureServe

Bruce A. Stein is Vice President and Chief Scientist for NatureServe, an organization dedicated to providing the scientific basis for effective conservation. As Chief Scientist, Dr. Stein is involved in working with a state-based network of biological inventories to make rigorous and objective ecological information accessible and useful to land managers, policy makers, and the general public.

Dr. Stein was lead editor of the book *Precious Heritage: The Status of Biodiversity in the United States* (Oxford Univ. Press), which has been described by Harvard University biologist E.O. Wilson as "the definitive text on U.S. biodiversity." He currently is serving as Editor-in-Chief of a major new project to develop an Encyclopedia of Natural Ecosystems and Open Space. Dr. Stein has authored more than 35 scientific reports and articles, and his work has been featured in such venues as the New York Times, National Public Radio, and Scientific American. A botanist by training, Dr. Stein is a specialist in plant inventory, classification, and conservation, with particular expertise in the botany of the United States and tropical South America. He was a senior scientist with The Nature Conservancy for more than a decade where he was involved in advising that organization on conservation priorities, and in establishing biological inventory programs throughout the western hemisphere. He is a research collaborator at the Smithsonian Institution's National Museum of Natural History, and serves on the oversight committee for the World Conservation Union's (IUCN) Red List Program, and on the governing board of the Global Biodiversity Information Facility.

A native of California, Dr. Stein holds a B.A. in Biology and Environmental Studies from the University of California, Santa Cruz and received his Ph.D. from Washington University, St. Louis in a joint program with the Missouri Botanical Garden.

David M. Theobald, Ph.D.

Colorado State University

David M. Theobald is an Associate Professor in the Department of Human Dimensions of Natural Resources, and a Research Scientist at the Natural Resource Ecology Lab, Colorado State University. He also was a David Smith Post-Doctoral Fellow with The Nature Conservancy. He is a conservation planner interested in understanding patterns of landscape change and their effects on wildlife habitat and biodiversity, especially in the Rocky Mountain West.

Dr. Theobald's current research includes developing ways to measure landscape connectivity for terrestrial and freshwater ecosystems using the FunConn and FLoWS tools for ArcGIS. He helped develop the Colorado Natural Diversity Information Source, an online source of information on wildlife, habitat, natural communities and plants in Colorado. He also has written and lectured extensively on landscape change in the West, including contributions to the *Atlas of the New West, Forest Fragmentation in the Central Rocky Mountains,* and *Rocky Mountain Futures.*

Dr. Theobald received his Ph.D. from the Department of Geography, University of Colorado, Boulder, and his M.A. from the Department of Geography, University of California, Santa Barbara.

URL: www.nrel.colostate.edu/~davet

Conservation Thresholds: Overview and Commentary

Reed F. Noss, Ph.D., University of Central Florida

Introduction

A “threshold” in ecology is a point at which one or many ecosystem properties change rapidly. Evidence is accumulating that the resilience of ecosystems is reduced by the activities of modern humans. Ecosystems can become “brittle” and, at some point along the human-disturbance continuum, suddenly shift to a new and often less desirable state (Merenlender, this volume).

In a sense, the last 200 years of world history have been a threshold. Not for 65 million years has the earth experienced such rapid change in biodiversity, a change so alarmingly negative that most conservation biologists are convinced that we are now well into the sixth mass extinction in geological history. There is no disagreement that humans alone are responsible for this new extinction event. Evidence also is increasing that individual species have extinction thresholds, corresponding to the habitat area or population size below which their decline to extinction can be precipitous and difficult to reverse (Fahrig 2002). Specifying the minimum population size or habitat area required for persistence, however, is challenging and dangerous.

A threshold is also a point of entering or beginning. Biological impoverishment, where the global rate of extinction outpaces the rate of speciation, began some time ago. Exactly when, we don’t know, but perhaps in the late Pleistocene at the time of the megafaunal extinctions. What we do know is that we are in desperate need of a new beginning, a threshold sparked by full realization of the consequences of our actions, as a species, across the earth — a beginning of human population stabilization, of steady-state economics, of ecological restoration in addition to habitat protection. We need to begin a commitment to help heal the wounds we have caused, a positive conservation threshold.

Healing the land must begin with good planning, for there are so many ways we can go wrong — or at least waste time and money — if we do not proceed intelligently and on the basis of the best available information. The Conservation Thresholds project of the Environmental Law Institute considers thresholds to be basic conservation parameters that can be used by planners to ensure that land use tools are science-based. These thresholds are concrete targets, such as the amount of land needing protection in a region in order to sustain all native species, the necessary width and location of habitat corridors, riparian buffer widths, and the distance between patches that must not be exceeded if populations of particular species are to persist. As the essays in this publication attest, highly specific rules of thumb should not be applied generally, as each case is special and idiosyncratic. Nevertheless, the science of conservation biology and the practice of land use planning now provide abundant case studies. From these many individual cases, we can start to draw some lessons and principles for how to proceed when case-specific information is deficient.

A major premise of the Conservation Thresholds project is that land use planners and conservation biologists need to interact, more often and more substantively. Fortunately, land use plans across the U.S. are now often, if not routinely, reviewed by at least some people with biological training. For major plans, scientific advisory panels often are established to provide independent review, ideally early in the process so that planning can be proactive instead of reactive (Noss et al. 1997, Berke, this volume). The tools for conservation and land use planning — GIS, remote sensing, reserve selection algorithms, planning and decision-support software, and more — are growing both more sophisticated and more user-friendly day by day (Merenlender, Perlman, Stein, Theobald, this volume). Nevertheless, much more can be done to assure that plans systematically incorporate rigorous methods and the best available information. The essays presented here provide abundant ideas for how this integration of science and planning can be accomplished.

We are in desperate need of a new beginning, a threshold sparked by full realization of the consequences of our actions, as a species, across the earth.

Planners appear to be grasping… for rules of thumb — relatively simple guidelines for how large parks should be, how wide corridors should be, and so on.

The Science in Land Use Planning

Many planners and decision-makers, and perhaps most of the public, now believe that land use planning or conservation planning should be science-based, or at least science-informed. Virtually all ecologists believe so. However, different people, and even different scientists, can have very different opinions about what science is or should be. We need some common understanding of the nature of science before we can define the proper role of science in land use planning.

The various essays in this volume reflect different impressions of science. Duane, from two cases he examines, comes to the rather pessimistic conclusion that the more successful case was distinguished by "relatively weak science or spatial detail on where biologically important resources were distributed until broad political support for the program had been achieved." He therefore recommends "good politics before good science." In contrast, the other authors represented here have a more positive view of the role of science in planning. For example, Stein emphasizes the need for reliable, map-based data to guide planning. Reliable data allow perceived conflicts to be separated from real conflicts.

Science is conventionally defined by such phrases as "the observation, identification, description, experimental investigation, and theoretical explanation of phenomena" (American Heritage Dictionary 2006); "systematic knowledge of the physical or material world gained through observation and experimentation," or "knowledge, as of facts or principles; knowledge gained by systematic study" (www.dictionary.com). The conventional model of science is the empiricist model, which produced "the scientific method" or hypothetico-deductive method that we all learned in school. The strict empiricist model of science has been severely challenged recently, however, with some scholars defining science more broadly as "an interactive, social activity in which multiple forms of reasoning and evidence, together with critical discussion, take place among a diverse scientific community" (Wallington and Moore 2005). Most authors agree, however, that science is (or should be) systematic, i.e., an ordered rational, as well as social, process.

In comparison with other ways of obtaining knowledge, science is distinguished by critical thinking rather than mythopoeic thinking. Science attempts to tear down its own mythology and its own dogma. Objectivity is a primary and indispensable norm of science, but as pointed out by Stern (2005) with some irony: "Science, despite its famous emphasis on achieving objectivity by eliminating human error, can make its claims of objectivity only because it relies on the subjective judgments of fallible human beings and social institutions to detect and correct errors made by other fallible humans and institutions."

In conservation planning, science is an ongoing, multi-stage, iterative process of identifying real-world problems, posing questions and hypotheses about mechanisms and possible solutions to these problems, gathering and analyzing map-based (e.g., GIS) data, testing preliminary maps against new data, developing alternative future scenarios, and coming up with a proposed solution, often in the form of a spatially explicit conservation design (Murphy and Noon 1992, Noss et al. 1997, Margules and Pressey 2000, Groves 2003, Theobald, this volume). This characterization of the science of conservation planning stands in stark contrast to the "science" described by Duane, which may have been more of an attempt by proponents of a plan to ram a particular value-laden solution down the throats of a reluctant public. The particular plan that Duane refers to, the Natural Heritage 2020 program in Nevada County, California, may have been dressed in the language and data of science, but cannot be taken as representative of science-based planning. Duane states that NH 2020 "attempted to use science to establish conservation goals before there was strong political support for the conservation goals themselves." Science can and should inform goal-setting, but it cannot provide the philosophical basis for goals. Science cannot tell us where to go — values tell us that — but once we determine direction, science is often essential to helping us get there. As Stein (this volume) points out, in many cases the conflicts that develop in planning exercises are more about values than about the role of science.

Science can definitely contribute to better planning; in fact, defensible planning cannot proceed without it. But what precisely does science have to offer? Planners appear to be grasping, in particular, for rules of thumb — relatively simple guidelines for how large parks should be, how wide corridors should be, and so on. Scientists, on the other hand, emphasize uncertainty and contingency (Merenlender, Perlman, Stein, this volume). Not long ago, I was approached by a planner from a neighboring county who needed to know (and right away) how wide corridors for Florida Scrub-Jays (a federally listed threatened species) need to be. They were writing new regulations and needed a precise number.

My answer, of course, was "it depends" (Perlman, this volume, identifies this as the "First Law of Ecology," and also notes that "there are surprisingly few universal truths in ecology and conservation biology"). In this case, it depends on habitat quality within the corridor (for example, the jays will not travel far through unsuitable habitat, such as closed forest); the length of the corridor (they only disperse so far); and the nature of adjacent habitat (if it is highly hostile, such as a dense subdivision or busy road, the corridor will need to be wider). I assured her that for any particular case, an expert on scrub-jays could provide a reasonably defensible recommendation on corridor width. But this was not good enough; she needed a fixed number that would apply across the board. Unfortunately, a fixed number is biologically indefensible. I know of no expert who would feel comfortable defending such a rule of thumb in court (though such rules of thumb may indeed be legally defensible in court; R. Kihslinger and J. Wilkinson, personal communication).

Some rules of thumb for science-based planning can be defended, but they are fairly general in nature. For example, Thomas et al. (1990) and Wilcove and Murphy (1991) offered spatial planning principles for avoiding the habitat fragmentation that imperils species such as the Northern Spotted Owl. Noss et al. (1997) rephrased these principles, and offered several others to guide comprehensive conservation planning. Among the principles that have withstood the test of time reasonably well are the following:

- *Nature is full of surprises.* Ecosystems are dynamic, not static, and often display non-linear dynamics with unpredictable outcomes (Merenlender, Stein this volume). The issue is, at whose expense the surprises will occur (Noss et al. 1997). It is reasonable to offer assurances to landowners and other parties who entered into a conservation plan that they will not bear the full cost of surprises. And it is reasonable to provide substantial public support for monitoring and adaptive management, which must often include changes in land use plans over time.
- *The fewer data or the more uncertainty, the more conservative a conservation plan should be.* This is a risk-averse or precautionary strategy — be willing to err on the side of protecting too much rather than too little.
- *Large conservation areas are better than small areas, all else being equal.* This does not mean that one large area is better than several smaller areas — that will vary case by case.
- *More conservation areas, spread across the planning landscape, are better than fewer areas.* This will assure that beta diversity (turnover in species composition among sites) is captured in the reserve network, and will help avoid "contagious catastrophes" and synchrony in population dynamics that could bring multiple populations of a species to extinction at once.
- *Connected is better than disconnected, all else being equal.* Here I am talking about maintaining or restoring natural connections (either through corridors or through permeability of the landscape matrix), not creating artificial corridors such as roadsides or powerline swaths. Connectivity is very species-specific and landscape-specific, however, so it is foolish and potentially dangerous to generalize further (Perlman, this volume).
- *Unfragmented habitat is better than fragmented habitat.* This refers to anthropogenic habitat fragmentation — by roads, developments, etc. — not to the heterogeneity or patchiness that is inherent to natural landscapes.
- *Roads generally are bad for native biodiversity.* It would be difficult to think of a landscape feature with more consistently negative ecological impacts than roads. Because human-inhabited landscapes will almost always contain roads, more research is required to understand wildlife-road interactions and to develop functional wildlife crossings, hydrological connectivity, and other mitigation measures.

Most of the essays in this volume refer to the issues above in various contexts and offer suggestions for planning, as did the Environmental Law Institute's (2003) Conservation Thresholds for Land Use Planners. It should be remembered that rules of thumb function best as empirical generalizations to guide planning in situations where case-specific data are lacking.

Growth, Densities, and Zoning: Not as Simple as it May Seem

Writer Ed Abbey famously pointed out that "growth for the sake of growth is the philosophy of the cancer cell." The highly significant correlation between growth in the gross domestic product and the increase in species listed as threatened or endangered in the U.S. certainly supports the notion that human population and economic growth have cancerous consequences (Czech et al. 2005). Nevertheless, we live in a society thoroughly committed to the philosophy that growth is good. At the same time, when surveyed in polls, citizens often rank growth (and associated ills such as sprawl and traffic congestion) among their primary concerns. It's a quality-of-life issue, but unfortunately it's much more than that—it's an issue of biological survival.

A landmark Supreme Court decision in 1926 (Village of Euclid, Ohio v. Ambler Realty Co., 272 U.S. 365) held that "every community has the right to determine its own character and the nature of development within." This right includes the decision of whether or not to grow. A few communities have established strict limits to growth, but in other cases — even when citizens are demanding an end to sprawl — county commissioners, city councils, and the developers who support them ensure that growth continues unfettered by meaningful restrictions. And the public keeps putting these people back into office. Yes, we have land use planning, but it can be argued that "traditional planning is essentially a mechanism for development of land, where development is broadly defined as moving from natural to more human-modified" (Theobald, this volume). Conservation biologists should be front and center in informing the public about the deeper consequences of growth: species extinctions, dysfunctional ecosystems, and loss of the ecosystem services upon which human well-being depend.

Land use planners struggle to deal with the schizophrenic opinions of the public concerning growth. Environmental laws and growth-management regulations have been marginally effective in controlling growth in some areas; in many other cases, growth is out of control. What can be done about it?

The essays contained herein do not dwell on the history of land use and conservation planning, and neither will I. Stein (this volume) points out that land use planning of some kind has been carried out through all of American history. In the late 1960s and 1970s, however, several factors converged to provide a basis for today's land use planning—notably, the great increase in public concern about environmental issues, and the publication in 1969 of Ian McHarg's seminal book, Design with Nature, which linked planning to the biophysical qualities of particular landscapes. It was not until the 1980s, as Stein notes, that the scientific basis for planning to conserve biodiversity started to come together under the banner of the new discipline of conservation biology (see also Perlman, this volume). This field continues to grow rapidly and develop new tools and approaches to conservation and land use planning.

Several authors in this volume express concern about the rather dismal state of planning from an ecological perspective, but there are some encouraging recent signs of improvement. Stein observes a considerable gulf between land use planners and conservation planners/scientists. Ecological concepts and scientific data and tools are incorporated crudely, if at all, in most land use plans and growth-management measures. Berke cites several examples of communities integrating scientific information and protection policies into local planning, but notes that ecological protection provisions tend to be the exception rather than the rule. Few programs take a balanced or holistic approach to planning. Among the core values that come through strongest in the highest-quality comprehensive plans is livability, an anthropocentric concept that encompasses a sense of place, social cohesion, attractive buildings and landscapes, safety, and accessibility to a mix of land uses. Application of science-based data and methods to planning is weak in virtually every case. Implementation of plan conservation elements, for example land acquisition to protect biodiversity hotspots or sensitive places from development, is typically poor.

Despite the overall poor performance of counties and other local jurisdictions in conservation planning, I am personally buoyed by referendums recently passed in two politically conservative Florida counties, where bonds totaling $120 million in two back-to-back measures (Brevard County) and $250 million in one measure (Sarasota County) were approved. Similar measures have passed elsewhere in the U.S., but alas, they remain few in number. Even in Florida, which has done much better than most states in some respects (especially land acquisition, including easements, where nearly $6 billion has been spent over the last two decades), Brody (2003) found that local comprehensive plans generally ignored data on biodiversity hotspots and other critical information. Only when an urgent threat arose — for example, a major new development proposal — did counties consult such data. Therefore, despite increasing awareness among scientists, planners, and some decision-makers that planning must be proactive in order to avoid ecological or policy "train wrecks" (in former Interior Secretary Bruce Babbitt's words), planning remains generally reactive (Berke, this volume). The barriers to incorporating science into planning remain formidable (Stein, this volume).

I often wonder exactly what is "smart growth," a commonly used term these days. In a heavily developed, over-populated sprawling metropolis such as Los Angeles, Phoenix, or Orlando, can any further growth be "smart"? I doubt it. But even in these metropolitan areas growth continues, so planners and citizens must find a way to channel that growth into areas where it does the least damage to biodiversity and ecological values. As Stein notes, even within the smart-growth community there are conflicts over values, for example open-space protection vs. affordable housing.

A common, long-standing approach to growth management is zoning with accompanying density restrictions. For example, areas may be zoned by counties, municipalities, towns, or villages as agricultural, low-density residential, high-density residential, industrial, commercial, and so on (see Ruther and Colton, this volume). It has traditionally been assumed that zoning exurban areas as agricultural or low-density will limit sprawl and help assure that much of the natural and scenic character of the landscape is maintained. However, recently that assumption has been questioned. For example, Merenlender points out that "policies that may curtail urban sprawl may not be the same as those needed for reducing exurban expansion trends." She notes that urban growth boundaries, which are a popular measure for reducing sprawl, can have "the perverse effect of pushing development beyond the cities." Ruther and Colton express this concern for Pima County, Arizona.

For Merenlender and Theobald, exurban development is potentially the greatest threat to the integrity of landscapes. Theobald provides data showing that the rate of growth of exurban areas exceeds the growth of urban areas. Large urban areas of relatively low density are growing 60% faster than smaller urban areas with higher density. The result is an overall footprint of low-density development that is 10 to 15 times larger than urban high-density development. This is a significant problem, especially where exurban development occurs in wildlands. We might surmise, however, that such development is less of a threat in intensive agricultural landscapes, which might be enriched by regrowth of native vegetation within large lots after agricultural abandonment.

Is low-density development, where ostensibly more natural habitat remains than in high-density development, really having 10 to 15 times the impact on biodiversity? Presumably many more native species are able to inhabit a landscape developed at low density than a high-density urban area. Yet, Merenlender cites a number of studies that show strong impacts of low-density development on native fauna. In contrast to the studies cited by Merenlender, however, other studies have shown that loss of native biodiversity and threats to adjacent natural areas increase with housing density. For example, Wilcove (1985) found that woodlots surrounded by suburban developments suffered higher rates of predation on artificial bird nests than woodlots surrounded by agricultural land with low housing densities, very likely because the suburbs contained subsidized populations of opportunistic mesocarnivores (e.g., house cats, raccoons,

Despite increasing awareness among scientists, planners, and some decision-makers that planning must be proactive in order to avoid ecological or policy "train wrecks" . . . planning remains generally reactive.

opossums, etc.). Similarly, Friesen et al. (1995) found significantly lower songbird abundance and diversity in forest blocks bordered by suburbs than in those with few or no nearby houses, again presumably because mesocarnivores are more abundant in suburbs.

Many studies, especially of birds, show that species diversity peaks approximately midway along urban-wildland gradients, where habitat diversity is high and where both disturbance-adapted and disturbance-sensitive species can be found. Nevertheless, the most sensitive species are retained only in the lowest density or wildland areas (Blair 1996, 2001, 2004, McKinney and Lockwood 2001, McKinney 2002). As home density in exurban areas increases, native species richness often drops (Hansen et al. 2005). Thus, moderate levels of urbanization or human disturbance in general may increase diversity locally, but decrease diversity regionally as the most sensitive species are lost (Noss 1983, Crooks et al. 2004, Marzluff 2005).

The only study I've found that directly compares (1) exurban clustered (high-density) housing developments and retained open space with (2) dispersed (low-density) housing developments is a recent paper from Colorado (Lenth et al. 2006). This study, which used undeveloped areas as controls, found that the two patterns of development generally did not differ in terms of densities of songbirds, nest density and survival of ground-nesting birds, presence of mammals, or percent cover and proportion of native vs. non-native plants. Both types of developments, however, were inferior to undeveloped areas in terms of native biodiversity. My reading of the literature suggests that the jury is still out over which is preferable for promoting viable populations of native species: clustered housing with clustered open space, or the same amount of housing dispersed across larger lots that still maintain "backyard" habitat.

In the spirit of full disclosure, I confess that I live in a low-density residential area. My last two homes have been on naturally vegetated 3-acre lots in Oregon and Florida, respectively. In Oregon, my family and I shared our lot with deer, coyotes, alligator lizards, and an occasional mountain lion. The home where we previously lived in a high-density suburb nearby had far fewer native species. In Florida, we have such splendid creatures as gopher tortoises, coral snakes, swallow-tailed kites, sandhill cranes, and an occasional otter in our yard. Meanwhile, high-density developments nearby — which are coming to dominate more and more of the landscape — have virtually no native vegetation and very few species of native plants and animals. Non-native species typically dominate. You can guess where a biologist would prefer to live and raise his children, so that they too have an opportunity to develop a deep biophilia (Wilson 1984). We don't want our children to be the last children in the woods (Louv 2005). I am convinced that biophilia is the *sine qua non* for biological conservation, and it is sustained only through intimate contact with nature, beginning in early childhood. Perlman (this volume) agrees that access to nature is critical for developing a "long-term nature conservation constituency."

Although urban environments with abundant parks, stream corridors, and other open space can inculcate biophilia, biophilia is not nurtured by high-density living, where your only neighbors are other people, household pets, lawn turf, rats, and cockroaches. People need contact with wild nature (Louv 2005, Miller 2006), which is rarely found within urban boundaries. It is not surprising, then, that according to studies cited by Merenlender, nearly half of all city dwellers would rather be living in the country or in small towns. But with our growing population, such a spread of humanity into the countryside would be disastrous. We are in a real dilemma!

Dispersed exurban development is an increasing trend that poses a significant threat to biodiversity, especially when it occurs in wildlands or ranchlands as opposed to intensive agricultural landscapes. Nevertheless, clustered development, even with reserved open space, is also destructive of habitat. There is one thing definitely worse than low-density exurban development: high-density suburban and exurban development across the entire landscape, especially when carried to the point where little of the original nature remains. In Florida, and undoubtedly elsewhere, we have the bizarre phenomenon of entire new cities springing up in wildlands and semi-natural ranchland, remote from existing urban areas. These are mostly very high-density developments, and thus might seem acceptable to many in the smart-growth community, but they are far from benign. They fragment habitat for wide-ranging species, such as the Florida panther and black bear, at a regional scale; their residents complain about smoke from natural and prescribed fires on nearby conservation areas, which limits the ability of land managers to manage Florida's fire-dependent vegetation; and perhaps worst of all, the roads that lead to these new cities increase markedly in traffic volume, which in turn increases roadkill, the primary source of mortality for many species (Trombulak and Frissell 2000).

It is important to recognize that when a community plans and zones for new development, it may specify an authorized development density (maximum number of dwelling units per acre), a minimum lot size (amount of land that must be conveyed with each individual unit), or both. It may also allow for "planned unit developments" that meet a density requirement in different ways with approval of the local government. If the zoning ordinance or planned-unit-development ordinance allows development of multiple units on a large parcel at a given density, it is palpably superior to cluster those units in a corner of the site and leave the remainder of the site in its natural condition. The exact location and size of the reserved area ideally would be determined by its biological values and the landscape context. However, if the local government simply imposes a minimum lot size for by-right development, while not providing for clustering or planned unit development, then it is better that lots be as large as possible — the lowest density — so that more natural habitat remains on each lot. The habitat value of large lots can be improved if deed restrictions or other measures limit the conversion of natural vegetation permissible on each lot.

What, then, is the best possible world of regional land use planning? From my readings of the essays in this volume and my own inclinations, I suggest it should include the following elements:

1. Much more conservation area, as strictly protected as possible, in the landscape, either through public acquisition (fee simple or conservation easements) or through trading (transfer) of development rights (see Merenlender) or other incentives. Functional corridors should be provided to connect conservation areas.
2. The landscape surrounding conservation areas should be kept at very low housing density and low-intensity land use, to provide buffer zones between conservation areas and higher-density development and to provide a permeable landscape that will enable many organisms to move among conservation areas. Landscapes can be kept at low density through many of the same mechanisms as above (conservation easements, trading of development rights) as well as through regulations.
3. Limit high-density development to lands within strictly defined development area boundaries. Provide parks and, where possible, connecting corridors throughout this landscape, both to serve the needs of native species and to make nature accessible to people. Clustered developments with retained open space can often serve this end.

This three-part scenario may be considered unrealistic by those who assume that (1) continued high population growth is inevitable; and (2) not enough public money is available to protect land. I do not accept either assumption. First, as we've seen, the Supreme Court has affirmed the right of communities to determine their own nature, which may include limiting growth. Second, considering the vast amount of money that society, through its government, is willing to spend on war and other questionable causes, to ask that a significant chunk of that money be shifted to nature conservation is not unreasonable. Moreover, the number of billionaires in the world has been increasing. Surely some of those people will be willing to make a substantial investment in conservation.

Hierarchical Planning and Regionalism

Effective and comprehensive land use planning must be carried out at multiple spatial scales. Berke (this volume) points out the spatial mismatch "between the scale at which local governments need to plan and manage to effectively protect landscape ecological resources and the scale at which land use planning and decision making is traditionally done." The variable but relevant scale of the "region" is useful for integrating concerns from both higher (global, continental) and lower (local) scales. A proliferation of

Effective and comprehensive land use planning must be carried out at multiple spatial scales.

disconnected local plans makes coordinated regional planning extremely difficult. Theobald emphasizes the “need to think far and wide: to think relatively far into the future about broad, wide landscapes.” Too much of planning, he notes, is carried out project-by-project. Although individual projects may have relatively little impact, the cumulative impacts of many projects lead to “death by a thousand cuts,” also described as a “tyranny of small decisions.”

Berke makes a strong case for regionalism, noting that it is “not just about consolidating little boxes to save money and limit duplicating municipal services,” but also about “limiting consumption of environmentally sensitive areas and open spaces on the urban fringe by channeling new growth towards the areas that are most suitable.” Berke is confident that regionalism is experiencing a rebirth, as exemplified by the devolution of responsibility for habitat protection for endangered species from federal agencies to public and private entities on a regional scale. Regional-scale Habitat Conservation Plans (HCPs) and, in California, Natural Community Conservation Plans (NCCPs) are representative of this trend. When properly guided and reviewed by independent science advisors (which is required in the case of NCCPs), such plans often make substantial contributions to conservation while making permitting less arduous for developers and landowners. In Florida, seven counties have come together under the umbrella of myregion.org and the related “Naturally Central Florida” initiative to examine alternative future growth scenarios and highlight key landscapes in need of protection (www.myregion.org/Aboutimyregionorgi/ResearchPublications/tabid/65/Default.aspx).

Conservation Planning Methods, Performance Measures, and Thresholds

For conservation planning — or any land use planning that gives due attention to biodiversity conservation — the overarching question is at what level of habitat loss and fragmentation does population viability and richness of native species begin to decline precipitously? A defensible land use plan would be one that maintains natural habitat in an amount, configuration, and quality safely above that threshold. The concept of the “minimum viable population (MVP) size,” above which persistence is virtually assured, dominated much of early conservation biology (Shaffer 1981). Unease about specifying such a limit in the face of uncertainty, combined with the fear that managers may manage a population down to an ostensible MVP, which later proves to be too small, has brought the concept into disfavor. Theoretically, MVP thresholds may indeed exist, but our ability to specify such thresholds is limited.

There may also be a “minimum viable metapopulation size,” the number of subpopulations that allow a metapopulation to persist (Hanski et al. 1996). In such cases a species may occupy a decreasing fraction of the available habitat until a threshold is reached, at which point the species is not able to maintain a positive balance between local extinctions and local recolonizations; the result is extinction even if some suitable habitat remains. Critical thresholds of habitat have been found for some organisms, for example amphibians (Homan et al. 2004) and butterflies (Hanski and Ovaskainen 2000). Considering multiple species, thresholds of habitat amount, below which species richness drops precipitously, are expected but have not been clearly documented. Based on computer simulations, Fahrig (1997) suggested that above 20% habitat cover, species persistence was virtually assured, regardless of habitat configuration. Other studies, however, have found that fragmentation of habitat can lead to declines beyond those attributable to habitat loss (reviewed in Noss et al. 2005).

The flip side to the question of habitat loss thresholds is the common question of conservation planning: how much is enough? That is, how much land must be conserved in relatively natural condition to meet conservation goals? Although some have questioned the generalization that roughly 50% of a region must be maintained as natural area in order to meet such well-accepted conservation goals as maintaining viable populations of native species, representing natural ecosystems across their range of variation, and maintaining ecological and evolutionary processes (Noss 1992), individual studies and reviews have generally supported this estimate (Noss 1996, Svancara et al. 2005). Although the required amount of land will vary widely from region to region due to such factors as environmental heterogeneity and the degree of endemism, the range of estimates generally falls within 25-75%.

Some conservation planning and site selection methods are discussed here by Merenlender and Stein. Ruther and Colton provide a case study of an ambitious plan for Pima County, Arizona. Merenlender makes the important point that biological resources are not interchangeable, hence it is difficult to solve the tradeoff between conserving one type of habitat versus another – in short, an apples-and-oranges problem. So, for example, it would be foolish to select a site that contains part of a forest and part of a wetland, if neither is large and intact enough to be ecologically functional; yet that's precisely where an "efficient" site selection method may lead us.

Merenlender suggests that the only solution is to decouple multiple benefits in the prioritization process when they are uncorrelated in space. This means, of course, that conservation planning will be less efficient, and thresholds for "how much is enough" will be higher. In any case, good data and proper use of site-selection algorithms alone will not assure success of a plan. As demonstrated in Pima County, success depends on an auspicious combination of high-quality information, visionary leadership, a linkage between and translation of science and planning, and solid funding (Ruther and Colton, this volume). The Pima County example also demonstrates that the listing of a species, in this case the Cactus Ferruginous Pygmy Owl, under the U.S. Endangered Species Act often helps jump-start a major planning effort; the listing of the California Gnatcatcher did the same for southern coastal California (Atwood and Noss 1994).

Conservation and land use planning invariably involve maps. But maps must be used wisely. Duane warns that conservation plans (such as NH 2020) that present maps highlighting areas warranting conservation are dangerous, because they mobilize backlash from private-property-rights enthusiasts. On the other hand, most of the other essays in this volume speak directly or indirectly to the value of maps in displaying alternative future scenarios and planning options in a transparent way to the public (see Stein, Theobald, this volume). Nothing but maps can do this — a picture is worth a thousand words. In Florida, I have found that even quite "radical" maps of statewide conservation networks provoked little backlash, but instead motivated state planners, scientists, and conservationists to refine the maps into defensible priorities for protection. A limitation of maps, for example of species occurrences, is that they often represent presence-only data. Field surveys ideally should provide presence-absence data, since it can be as important to know where particular features do not occur as where they do occur (Ruther and Colton, this volume).

In all cases, it is critical that land use plans be monitored carefully to determine whether their goals are being met. This requires reliable indicators of ecological integrity, a huge and challenging topic that is largely outside the scope of this project. Berke touches on this topic and provides examples of promising case studies. Seattle, for instance, has a monitoring program for its comprehensive plan, which analyzes whether the city is accommodating growth in the manner specified in the plan. Santa Monica provides another example, where sustainability indicators have been monitored since 1994 and the results are communicated to the public. Theobald also emphasizes the need for "closing the loop" after land use planning decisions are made, by making a commitment to monitoring, evaluating, and adjusting on a regular (annual to semi-annual) basis.

The essays in this volume identify problems related to bottom-up (e.g., purely local or project-by-project) planning, as well as problems associated with top-down planning (e.g., the command-and-control mentality). I suggest we need a balance of top-down and bottom-up conservation approaches. A top-down approach offers the advantages of seeing the big picture and evaluating local efforts within a broader context. Followed exclusively, however, it ignores local knowledge, including that of natural history, and may not meet the needs of local people. The bottom-up approach, on the other hand, suffers frequently from tunnel vision, parochialism, and sometimes ecological illiteracy; however, it is democratic and grounded in local values. If we can figure out a way to combine the advantages of top-down and bottom-up planning, while avoiding the pitfalls, we will greatly improve the prospects for land use planning. Nevertheless, political and legal factors will continue to constrain the development of biologically optimal plans (Ruther and Colton, this volume).

The integration of science into land use planning will improve both enterprises: it will make science more relevant and useful to society, and it will make land use planning more accountable, sustainable, and grounded in the real world of biophysical ecosystems on which human society will always depend.

Summary and Conclusions

The integration of science into land use planning will improve both enterprises: it will make science more relevant and useful to society, and it will make land use planning more accountable, sustainable, and grounded in the real world of biophysical ecosystems on which human society will always depend. Scientists involved in land use planning should not be expected to abandon their scientific and eco-centric values, but they must humble themselves and be willing to work constructively with people who hold very different value systems (Duane, Stein, this volume). Progress is being made in bridging the divide between conservation science and land use planning, as most of the essays in this volume attest. Scientists are more willing today than in the past to engage in real-world planning and management, in part because applied science is finally becoming accepted as a legitimate scientific activity. Applied scientists face fewer obstacles and less snobbery than previously from their academic peers in basic science. In many cases, too, planners are becoming better educated in ecology and conservation biology. They also are responding to increasing public concern about sprawl, loss of open space, traffic, and other ills of poorly managed growth.

Further progress in the integration of science and planning toward the betterment of natural and human cultural systems requires the following:

- Building human capacity and expertise. As Stein notes, the ability of the Internet to provide vast quantities of unfiltered information increases the need for scientists to filter and interpret this information.
- Training of individuals with expertise and skills in both conservation science and land use planning (Ruther and Colton, this volume).
- Recognizing that the role of science is not to impose a particular set of values or to specify a single solution to a planning problem, but rather to identify the range of values at stake, the consequences of various decisions and alternative future scenarios, and those solutions that meet established goals.
- Providing both carrots and sticks to encourage good planning. Duane makes clear that strong regulatory requirements are good motivators that bring developers to the table, and allow them to support comprehensive planning and mitigation rather than piecemeal project-by-project permitting.
- Consideration of site content and landscape context in planning. Maps must be used wisely.
- Recognition that rules of thumb are generalizations. Experts are needed to interpret such rules to specific cases. Often the needs of particular species must be considered in detail to specify such things as patch size and corridor width. Each case is unique, but we should be open to lessons that can be transferred more widely.
- Development of a planning philosophy and strategy that is proactive rather than reactive.

Planning goals should incorporate a broad range of widely shared values about nature and human welfare. Although Duane suggests that anthropocentric goals are preferable to biocentric goals because they are better accepted by more people, anthropocentric goals are actually a subset of biocentric goals. Both types of goals are less comprehensive than truly ecocentric goals (Callicott 2005), which may provide the ideal basis for land use planning because it takes into consideration the long-term sustainability of both human and natural systems and values.

As Duane notes, "good science may need good politics to be effective in guiding public conservation planning, but it is not necessarily apparent that good politics will always embrace good science." I believe that increasing public support for good science and for conservation ultimately requires lifelong environmental education and contact with nature. Without these, people will not think of nature when they go to the polls to vote. We need to develop an informed and impassioned constituency for conservation (Perlman, this volume). It is imperative, then, that planning provides people easy access to nature, from the urban core to the hinterlands. People will want to save what they know and love through personal contact (Miller 2006).

Literature Cited

American Heritage Dictionary of the English Language, The. 2006. Fourth Edition

Houghton Mifflin Company. http://dictionary.reference.com/browse/science (Accessed February 27, 2007.)

Atwood, J.L., and R.F. Noss. 1994. Gnatcatchers and natural community conservation planning: Have we really avoided a train wreck? *Illahee: Journal of the Northwest Environment*. 10:123-130.

Blair, R.B. 1996. Land use and avian species along an urban gradient. *Ecological Applications*. 6:506-519.

Blair, R.B. 2001. Creating a homogeneous avifauna. In J.M. Marzluff, R. Bowman, and R.A. Donnelly, eds. *Avian Conservation and Ecology in an Urbanizing World.* Norwell, MA.: Kluwer Academic Press.

Blair, R. 2004. The effects of urban sprawl on birds at multiple levels of biological organization. *Ecology and Society.* 9(5): 2 http://www.ecologyandsociety.org/vol9/iss5/art2/. (Accessed February 27, 2007)

Brody, S.A. 2003. Examining the effects of biodiversity on the ability of local plans to manage ecological systems. *Journal of Environmental Planning and Management.* 46:817-837.

Callicott, J.B. 2005. Conservation values and ethics. In M.J. Groom, G.K. Meffe, and R.C. Carroll, eds. *Principles of Conservation Biology.* Third edition. Sunderland, MA: Sinauer Associates.

Crooks, K.R., A.V. Suarez, and D.T. Bolger. 2004. Avian assemblages along a gradient of urbanization in a highly fragmented landscape. *Biological Conservation.* 115:451-462.

Czech, B., D.L. Trauger, J. Farley, R. Costanza, H.E. Daly, C.A.S. Hall, R.F. Noss, L. Krall, and P.R. Krausman. 2005. Establishing indicators for biodiversity. *Science*. 308:791-792.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. *Journal of Wildlife Management.* 61:603-610.

Fahrig, L. 2002. Effect of habitat fragmentation on the extinction threshold: A synthesis. *Ecological Applications.* 12:346-353.

Friesen, L.E., P.F.J. Eagles, and R.J. MacKay. 1995. Effects of residential development on forest-dwelling neotropical migratory songbirds. *Conservation Biology.* 9:1408-1414.

Groves, C.R. 2003. *Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity.* Washington, D.C.: Island Press.

Hansen, A.J., R.L. Knight, J.M. Marzluff, S. Powell, K. Brown, P.H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications*. 15:1893-1905.

Hanski, I., and O. Ovaskainen. 2000. The metapopulation capacity of a fragmented landscape. *Nature.* 404:755-758.

Hanski, I., A. Moilanen, and M. Gyllenberg. 1996. Minimum viable metapopulation size. *American Naturalist.* 147:527-541.

Homan, R.N., B.S. Windmiller, and J.M. Reed. 2004. Critical thresholds associated with habitat loss for two vernal pool-breeding amphibians. *Ecological Applications.* 14:1547-1553.

Kennedy, C., J. Wilkinson, and J. Balch. 2003. *Conservation Thresholds for Land Use Planners.* Washington D.C.: Environmental Law Institute.

Lenth, B.A., R.L. Knight, and W.C. Gilbert. 2006. Conservation value of clustered housing developments. *Conservation Biology.* 20:1445-1456.

Louv, R. 2005. *Last Child in the Woods: Saving our Children from Nature-Deficit disorder.* Chapel Hill, NC: Algonquin Books.

Margules, C.R., and R.L. Pressey. 2000. Systematic conservation planning. *Nature.* 405:243-253.

Marzluff, J.M. 2005. Island biogeography for an urbanizing world: how extinction and colonization may determine biological diversity in human-dominated landscapes. *Urban Ecosystems.* 8:157-177.

McHarg, I. 1969. *Design with Nature.* Garden City, NY: Natural History Press.

McKinney, M.L. 2002. Urbanization, biodiversity, and conservation. *BioScience.* 52:883-890.

McKinney, M.L., and J.L. Lockwood (eds.). 2001. *Biotic Homogenization.* New York: Kluwer Academic/Plenum Publishers.

Miller, J.R. 2006. Restoration, reconciliation, and reconnecting with nature nearby. *Biological Conservation.* 127:356-361.

Murphy, D.D., and B.R. Noon. 1992. Integrating scientific methods with habitat conservation planning: reserve design for northern spotted owls. *Ecological Applications.* 2:3-17.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. *BioScience.* 33:700-706.

Noss, R.F. 1992. The Wildlands Project: Land conservation strategy. *Wild Earth.* (Special Issue): 10-25.

Noss, R.F. 1996. Protected areas: How much is enough? In R.G. Wright, ed. *National Parks and Protected Areas.* Cambridge, MA: Blackwell.

Noss, R.F., B. Csuti, and M.J. Groom. 2005. Habitat fragmentation. In M.J. Groom, G.K. Meffe, and R.C. Carroll, eds. *Principles of Conservation Biology.* Third edition. Sunderland, MA: Sinauer Associates.

Noss, R.F., M.A. O'Connell, and D.D. Murphy. 1997. *The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act.* Washington, D.C.: Island Press.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. *BioScience.* 31:131-134.

Stern, P.C. 2005. Deliberative methods for understanding environmental systems. *BioScience.* 55:976-982.

Svancara, L.K., R. Brannon, J.M. Scott, C.R. Groves, R.F. Noss, and R.L. Pressey. 2005. Policy-driven vs. evidence-based conservation: a review of political targets and biological needs. *BioScience.* 55:989-995.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. *A Conservation Strategy for the Spotted Owl: Interagency Committee to Address the Conservation of the Northern Spotted Owl.* Portland Oregon: U.S. Department of Agriculture.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology.* 14:18-30.

Wallington, T.J., and S.A. Moore. 2005. Ecology, values, and objectivity: advancing the debate. *BioScience.* 55:873-878.

Wilcove, D. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology.* 66:1211-1214.

Wilcove, D., and Murphy, D. 1991. The spotted owl controversy and conservation biology. *Conservation Biology.* 5:261-262.

Wilson, E.O. 1984. *Biophilia.* Cambridge: Harvard University Press

Challenges in bridging conservation science and land use planning

David M. Theobald, Ph.D., Colorado State University

Introduction

In this essay I address some of the key issues that occur at the interface between conservation science, land use planning, and land use decision-making. In doing so, I identify some challenges in bridging conservation science and land use planning. One place to start addressing these questions is to identify the premise of each of the three disciplines or groups of professionals involved, and examine existing interactions between them; then we can begin to address how they could interrelate more productively.

Conservation science typically is built on the premise that "more information will better inform land use decision makers regarding the potential ecological consequences of particular land use plans or actions" (Theobald et al. 2005). *Land use planning* seeks to order and regulate the use of land in an efficient way. The *policy process* typically proceeds through participants (citizens, developers, etc.) who are seeking values through institutions (city, county, state, federal planning policies and devices) that affect the environment (Clark 2002). The field of *conservation planning* is an interdisciplinary enterprise and involves all of these.

One way to organize how to think about conservation planning is through a conceptual framework. This framework helps organize which activities are primarily within the purview of conservation science, in the environmental policy arena, and at the interface. It also helps to establish how data is converted to information through analysis, and how information in turn is combined with the knowledge and experience of decision-makers to produce decisions (Figure 1). Conservation scientists are typically responsible for combining ecological theories and principles with careful basic data collection and monitoring, which are guided by geographic information science, to convert these data into useful information in the form of metrics and indicators. Statistical analyses and spatial models are used to develop explicit and repeatable indicators of human modification of the environment.

Determining which indicators are useful requires guidance from those who will apply the information: decision-makers, planners, and citizens. How the indicators are generated is typically guided by conservation scientists. Planners help facilitate and coordinate the technical information within the context of policies and plans, increasingly through establishing alternative scenarios that reflect specific land use planning assumptions. This framework is roughly how I think about the various interactions of scientists, planners, and decision-makers.

Below I will simply identify *what* I believe the important issues are, and *why* I believe them to be important. I will tackle the challenge of *how* these issues might best be addressed to a lesser degree. Scientists, planners, decision-makers, citizens alike will need to work collaboratively to develop solutions to these important conservation challenges.

What are the major gaps in the conservation biology research agenda that need to be filled to improve land use and conservation planning?

Exurbanization

Urbanization or "sprawl" is frequently identified as a leading threat to biodiversity, both nationally and globally. In the US, this call to focus on conversion of land to urban uses has been substantiated through analyses and assessments based on the Natural Resource Conservation Service's National Resource Inventory (NRI), a nationwide land-cover change monitoring system. For example, The Conservation Fund's "Green Infrastructure" approach (Benedict and McMahon 2001) cited NRI data to argue that land resources in the US have been used inefficiently, because the rate of urbanized land outpaced the increase in population from 1982 to 1997, 47.1% to 17.0%. That is, the area of urbanized land per person increased recently, signifying sprawl.

Fair enough. But let's examine these data a little further to see if we can refine the notion of "urbanized land." First, the Green Infrastructure study is based on a Brookings Institute study (Fulton et al. 2001) that was conducted for the 282 most highly urbanized counties in the US (US Census Metropolitan Statistical Areas). But what kinds of growth patterns and rates are occurring in the remaining nearly 3,000 counties? When the NRI data are re-analyzed to include all counties — not just MSAs — urban areas have expanded slightly less: 33.9% between 1982 and 1997, as compared to 47.1% for MSAs.

Second, most analyses combine data from two types of urbanized land defined by the NRI: so-called *small urban and built-up areas* (less than ten acres in size, or relatively high density) and *large urban and built-up areas* (greater than ten acres in size, relatively low density). By comparison, note that the US Census defines urban as at least 1,000 people per square mile, or ~1.6 people per acre, 1 housing unit per ~1.5 acres. These data suggest that although development at relatively high housing density is occurring, the rate of growth for exurban areas – "large" urban areas of relatively low density — is over 60% higher than "small" urban areas. That is, exurban areas grew by 48.8% from 1982-1997, as compared to 29.8% for small urban areas (and 65.5% vs. 42.6% in 1982-2001). The bottom line is that exurbanization, including in non-MSA counties, is occurring at a more rapid rate than urbanization. Moreover, the overall footprint (not the rate of expansion) of low-density development is over 10 times larger than the urban high density development: 77.6 vs. 6.7 million acres. This finding is similar to results from analysis of growth patterns using a finer-grained representation based on census block data (Theobald 2001 2005). I believe that this lower-density exurban development is at least as important as the types of land use change typically associated with urbanization, because it is even more resource-consumptive, expansive, and challenging to conservation of biodiversity (Theobald 2001, Hansen et al. 2002, Maestes et al. 2003).

There are a variety of important consequences of these low-density land use changes that conservation science has begun and should continue to address (Hansen et al. 2005), in particular effects on wide-ranging species, corridors, and movement patterns (Crooks and Sanjayan 2006, Hilty et al. 2006); more precise estimation of disturbance zones around houses (Odell et al. 2003, Fraterrigo and Wiens 2005); and determining how large subdivision "reserves" or open space should be to protect native species (e.g., Theobald 2003, Lenth et al. 2006). Also, conservation subdivision design (Theobald et al. 1997, Arendt 2004) has emerged as a common way to reduce the impacts associated with development (e.g., Pejchar et al. 2007).

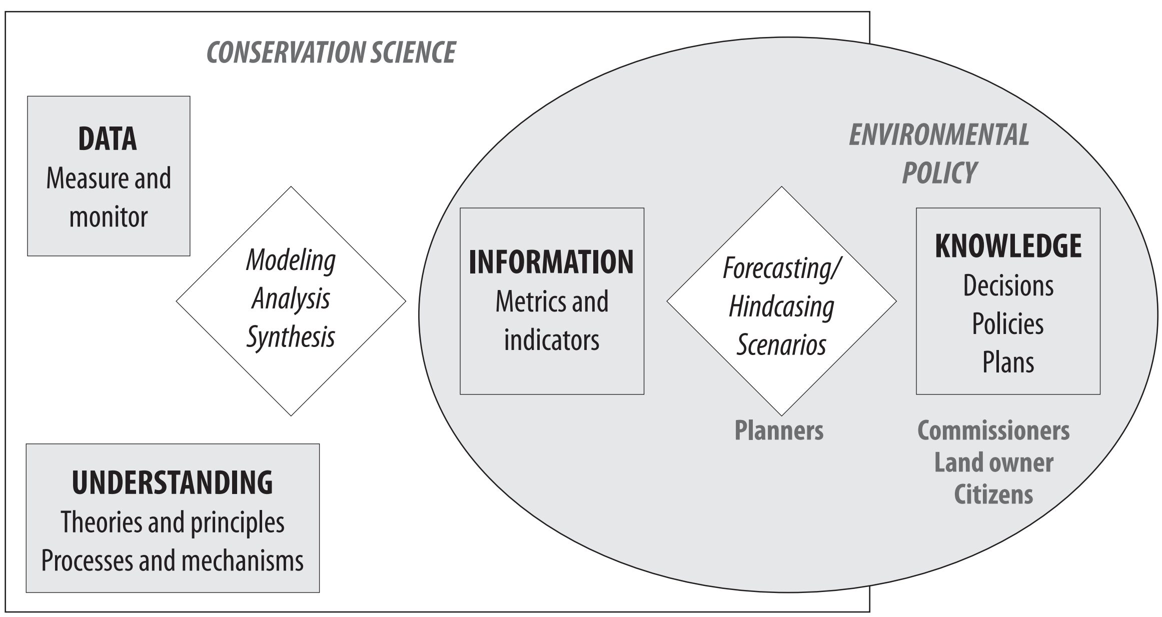

FIGURE 1. A conceptual framework of how conservation science data are transformed by analysis into information that informs the land use planning process. The rectangle represents the area where conservation scientists are active, while the circle represents the environmental policy arena. Modified from Theobald et al. (2005).

Protected areas: What are we protecting, from what, and why?

The most common method to conserve biodiversity has been to establish protected areas (i.e. reserves, parks, heritage sites, etc.). Yet we have limited understanding of how well this approach works. We need to better understand what we are protecting, what are the threats that we are protecting it from, and why — what values we are protecting. Key to overcoming these limitations is a more comprehensive conceptual framework, complemented with a consistent, comprehensive, and current spatial dataset of protected areas, and methods that examine the landscape context of protected areas.

Currently the conceptual framework that guides most conservation science on protected areas and land stewardship is related to whether land is managed for permanent biodiversity maintenance through some legal and/or institutional mechanism. For example, the World Conservation Union (IUCN) and the US Geological Survey's Gap Analysis Project (GAP) use this approach (Scott et al. 1993, Davey 1998). The IUCN designates 6 categories (IUCN 1994), ranging from strict nature or scientific reserve to national parks to multiple-use managed areas (private lands in general are not included). GAP devised a stewardship classification with four status classes (Csuti and Crist 2000): (1) permanent protection from conversion of natural land cover, with natural disturbance events allowed; (2) permanent protection and some suppression of natural disturbances; (3) some extractive uses permitted; and (4) no protection from conversion of natural land cover.

Substantial progress has been made recently on conceptual frameworks. The IUCN categories have been revised substantially in the Conservation Measures Partnership, a collaborative effort, mostly among non-governmental organizations, that includes The Nature Conservancy, World Wildlife Fund, and Conservation International, in addition to the IUCN. They recognize 11 classes of direct threats (IUCN-CMP 2006): residential & commercial development; agriculture & aquaculture; energy production & mining; transportation & service corridors; biological resource use; human intrusions & disturbance (recreation, war, etc.); natural system modifications (e.g., fire suppression); invasive species & genes; pollution; geologic events; and climate change & severe weather.

Changes in land use on privately-owned land need to be better incorporated into these frameworks (Theobald 2004). An important weakness is that our level of understanding of protection on private lands is particularly poor, in part because of GAP's focus on permanently protected public lands — note that private lands are almost always placed wholesale into the lowest protection-level category. It has also been a low priority of federal assessment efforts to develop stewardship databases. For example, I estimate that most state and regional GAP efforts allocated ten to twenty times the funding for land cover and species distribution mapping as for stewardship mapping (ownership, management, protected areas). The result is that most local-level protected lands (city, county, township), and nearly all conservation easements on private lands, have not been incorporated into regional assessments.

Finally, because threats are often particularly acute at the interface of private and public land, we need to develop new methods to move beyond examining just the in situ *landscape content* of a conserved area (or park) using levels of threat or protection. In addition to content, the *landscape content* must be considered as well.

Assess what conservation easements conserve

Of the 11.8 million acres that have been protected by US local and regional land trusts, over half (6.2 million acres) have been protected through conservation easements (LTA 2005). This is a trend that nearly everyone applauds, and one that no one—(well, not many) has questioned. Merenlender et al. (2004) have asked about the consequences of this trend, and concluded that: "Conservation biologists need a greater understanding of what natural resources are protected by conservation easements, the landowners that donate or sell them, and the institutions that hold and enforce them, in order to make useful recommendations about conserving and enhancing biodiversity on private lands in the United States today" (p. 73). It's a simple, but important, question: what is really being protected by conservation easements?

I believe that this lower-density exurban development is at least as important as the types of land use change typically associated with urbanization, because it is even more resource-consumptive, expansive, and challenging to conservation of biodiversity.

Behind this question are a few concerns: (a) descriptions of the benefits provided by easements are often too general to be useful; (b) we have poor infrastructure for data about where easements are located; and (c) few comprehensive assessments have been conducted of easements and the values they conserve.

By law, a description of the values protected by conservation easements must be provided to qualify for a federal tax deduction (note also that state-level tax credits are available in CA, CO, CT, DE, GA, MD, MS, NC, NM, NY, SC, and VA). The US Internal Revenue Code, 26 U.S.C. § 170(h)(4), defines "conservation purpose" as the following:

i. the preservation of land areas for outdoor recreation by, or the education of, the general public,
ii. the protection of a relatively natural habitat of fish, wildlife, or plants, or similar ecosystem,
iii. the preservation of open space (including farmland and forest land) where such preservation is—
    I. for the scenic enjoyment of the general public, or
    II. pursuant to a clearly delineated Federal, State, or local governmental conservation policy, and will yield a significant public benefit, or
iv. the preservation of an historically important land area or a certified historic structure.

As a result, the legal documentation of many easements has been a sentence or two drawn from the IRS code. From a conservation biology perspective, this is woefully inadequate: it lacks details about what type of habitat, what animal or plant occupies it, what timeframe, which public benefit, what designation was followed, etc.

Because the IRS emphasizes provision of "public benefit," it is important to understand a community's articulation of public benefit through government planning documents. For example, Ernst et al. (2006) examined 24 publicly adopted documents for Larimer County, Colorado, and generated a typology that lists, in addition to protection of habitat (i.e. rare & imperiled species), other values such as watersheds, viewsheds, community open space, agricultural lands, cultural resources, recreational opportunities, and protection from hazards (Table 1). For each of the individual values that are identified in a given community, detailed criteria should be specified that helps to assess the presence, status, and/or condition of the value to be protected by the easement.

In addition, the data resources to track and inventory the extensive and complex changes in conserved lands are poor to non-existent. The Land Trust Census provides some useful baseline information, but it does not track details below the county level, which is critical when conducting any sort of assessment. Also, the societal values that we are seeking to protect remain poorly understood, and the insights from our social science colleagues will be particularly valuable here (Mascia et al. 2003). "While the biological sciences are indispensable for describing the biological consequences of a particular management strategy, they cannot indicate whether or not those consequences are desirable. Desirability is a subjective, social condition and it is differences of desirability that form the foundation for social conflict" (Manfredo et al. 2004).

Identify high priority habitat (important conservation areas)

One of the largest gaps in conservation planning is the need to simply identify locations of high value or importance – also known as high priority habitat (HPH). This need to narrow the focus of protection, rather than asserting that all areas are important, is substantiated by a number of key biological principles for conservation planning (Duerkson et al. 1996 Noss et al. 1997, Theobald et al. 2000): maintain large intact patches; protect habitat for rare and sensitive species; and protect rare landscape elements. In Colorado, we identified areas that have one or more important wildlife values, including rare native vegetation types, known distributions of sensitive and rare species, limiting habitat for economically important species, and areas with particularly high species richness (Theobald et al. 2000). A substantial need for mapping HPH remains, according to Lerner et al.'s (2006) recent review of all state Wildlife Conservation Strategies.

There are a number of scientific and technical challenges to mapping HPH. First, there is often disagreement about the two main types of habitat data that are used to generate maps of HPH: known occurrences and potentially suitable habitat. Data on known occurrences (e.g., from Natural Heritage Programs/NatureServe or state wildlife agencies)

TABLE 1. A typology of public benefits of conservation easements as articulated in Larimer County, Colorado planning documents. Adapted from Ernst et al. (2006).

Major type	Type	Public benefits of open space in Larimer County
Ecological	Protect or enhance habitat	General habitat and/or corridors
		For Threatened & Endangered species
		Sensitive environmental resources
		Biodiversity
		Buffering established protected areas
		Unique/outstanding physiographic features
	Protect watershed processes	Groundwater recharge areas
		Watershed, floodplain, wetland, riparian
		Environmental services (water & air quality)
		Stormwater storage & treatment
		Water quality
	Protect from hazards	Hazardous areas
		Reduce damages
Community	Protect agricultural	Agricultural land and water
	Protect Cultural	Rural character
		Historic buildings & lands, archeological sites, heritage sites, etc.
	Protect Recreation	Accessible open space
		Local and regional trail system
	Protect community values	Community separators
		Contiguity between open lands
		Buffer agricultural and urban interface
		Growth management
		Educational opportunities
		Community image & quality of life
		Tourism & commerce

and/or spatial distribution of a species are often considered a primary source for generating information on habitat. These data are typically produced directly from field observations of biologists or wildlife officers.

Data on potentially suitable habitat (PSH), such as those produced by a statistical model or from species-vegetation affinities, are also critical. Meta-population theory supports the idea that non-occupied habitat can be crucial for long-term viability of a meta-population. That is, the long-term persistence of a group of distinct but interacting populations often is greater because a population that goes extinct can be re-colonized by nearby populations. As a result, we need to know not just where populations are currently using habitat, but also where they might likely be in the future — especially in the face of land use and global climate change. Data on PSH are also important from a practical perspective, because maps of known distributions are typically collected oppor-

There is general consensus among most conservation scientists about the need to inform broader, more regional or landscape-level planning.

tunistically rather than based on a rigorous sampling design or a census. Moreover, data on known distributions typically are available for a small proportion (less than 10%) of imperiled species in a state or ecoregion.

A standard way to generate an HPH map is to combine or stack layers that depict different types of habitat for each species of interest, and sum the score (weight or priority) at every location (e.g., Theobald et al. 2000). In this common method, a species that has more types of habitat identified for it (e.g., summer range, winter range, calving areas, etc.) will, on average, be disproportionately weighted compared to a species with fewer types of habitat. The number of habitat types often ranges from one to ten types. In addition, species (e.g., elk) that have very large geographic distributions are similarly disproportionately weighted compared to other species with smaller geographic extents (e.g., Boreal toad). One simple way to address these deficiencies is to normalize for each species by dividing by the summed values for all habitat types. Note that this also works well when computing the relative importance and role of a community or jurisdiction in protecting a species. Without some sort of normalization process, the resulting composite map reflecting important habitat areas for multiple species can be biased and extremely difficult to interpret.

What can land use planners and regulators do that would help lead to the conservation and recovery of biodiversity?

Land use planners and decision-makers play a pivotal role in helping the conservation and recovery of biodiversity on privately owned lands and waters. One common perspective of conservation planning is that the planning process simply needs better, more precise scientific information about what to conserve – should there be a 100-foot setback around a wetland, or is 500 feet required? This view is implicit in the typical scientific assumption that better information leads to better decisions. It also is captured in the sentiment: "if only the scientists could get it right." Better information is indeed part of the answer, and I address below a number of significant ways that I think we can do better in that regard.

A second question — "What information do planners need to enable them to turn traditional planning approaches into innovative conservation tools?" — presumes that there is no need to question the current planning approach. Some argue that traditional planning is essentially a mechanism for development of land, where development is broadly defined as moving from natural to more human-modified states (e.g., to cropland, to urban, etc.). I will not address this question further here, but simply note that I believe it is a fundamental issue to discuss whether the end goal of planning, that is to order and regulate the "efficient" use of land, needs to examine efficiency from a broader, conservation perspective.

Think big: Landscape-level thinking

There is general consensus among most conservation scientists about the need to inform broader, more regional or landscape-level planning (e.g., Noss et al. 1997, Theobald et al. 2000, Cohn and Lerner 2003, Theobald et al. 2005). This perspective has been popularized in the adage "think globally, act locally." It makes the case for each of us to consider the bigger issues when making relatively small decisions. Yet we face a fundamental challenge in conservation planning, because there is a critical mismatch between the scales at which we should think and the scales in which we act in both time and space.

One way to provide more focus to this issue of scale mismatch is to quantify the spatial overlap between the conservation area for a given species of interest (S) with an administrative or decision making unit (C). For example, suppose we are interested in exploring the role of a particular county, C, in conserving critical habitat for an imperiled species S. An indicator of *importance,* or the degree to which C plays a role in conservation of S is related to the proportion of the critical habitat that is found within the county (formally, the ratio of $S \cap C/S$). The larger the proportion (approaching 1.0), the more important a county is to conserving critical habitat. Conversely, if the proportion is small (approaching 0.0), then the county plays only a minor role. An indicator of *constraint* (or its opposite, freedom) is the proportion of a county that is critical habitat ($S \cap C/C$). If this proportion is large, then there is less freedom to plan where land use change might occur within the county.

A final indicator is the total *number of parties*, or the number of counties that have critical habitat of interest (the number of *C*s that intersect *S*).

If the importance indicator of *C* is low, for example if the county has only 10% of the critical habitat, then a county's actions (alone) will not likely be sufficient to conserve the critical habitat of interest. If the critical habitat is dispersed throughout a number of additional counties (~>10), such that the importance indicator is low for all of the involved counties, then this leads to a situation similar to "tragedy of the commons," where all individual counties rationally will not be strongly motivated to protect *S,* because their individual actions are not sufficient to conserve the conservation target. If the importance indicator is low for a given county, but high for other counties that contain critical habitat, then the given county has a smaller role.

Note that there is another important aspect to the way we consider the cumulative context of decision-making. Individual decisions that allow a particular land use change to occur, often made singly and independently, may have only small effects. Yet over time they can accumulate to generate a large effect — dramatically known as "death by a thousand cuts," or "the tyranny of small decisions" (Kahn 1966, Odum 1982). We must be sure to establish an appropriate baseline or frame of reference for measuring change. Should a land use decision be based on what proportion of current habitat might be affected by a proposed land use change, or on what proportion of total (historical) habitat we will allow to be affected?

Think far and wide: Augment master plans with alternative scenarios

Following the previous discussion about scale mismatch is the need to think far and wide: to think relatively far into the future about broad, wide landscapes. This kind of thinking is commonly conducted through "master" or "vision" plans that are created with a ten- to twenty-year time frame in mind. These are useful to be sure, generally providing broad vision statements or community goals, but they provide little in the way of concrete visualization of how a particular planning policy or tool may shape a community's future. How many units will there be in the future? Where will they be located? What will the impact be on the road system? How much land will be converted to residential use? What are the likely differences between alternative policies?

Increasingly, conservation planners are generating information about possible scenarios that may occur over scales as long as 100 years and as broad as ecoregions (e.g., Steinitz et al. 1996). One common approach to exploring possible growth scenarios is to develop simulation models of land use change. The goal is to forecast the land use pattern at perhaps 5-10 year increments. These models have been developed using a range of approaches, such as cellular automata rules (e.g., Batty 1997, SLEUTH, Clark et al. 1997); spatial transition probabilities (SERGoM, Theobald 2005); regression-based relationships (Bradshaw and Mueller 1998); or planning scenarios (Steinitz et al. 1996).

An alternative to simulation modeling is to analyze the logical consequences (or end state) of a variety of different possible policy responses, often called a *build-out analysis* (Lacy 1992, Theobald and Hobbs 2002, Sawyer et al. 2005). That is, rather than attempting to predict "the right pattern" at a series of time-steps, build-out analysis focuses on examining, "in the fullness of time," a variety of possible planning/policy scenarios. A build-out analysis has clear advantages: it provides a simpler, more transparent method to examine patterns of growth, with more direct linkages between the possible outcomes and the policy levers that produce them.

Build-out scenarios help inform decisions that can be more resilient to the uncertainties of tomorrow. A scenario is defined as "a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points" (Kahn and Wiener 1967). Scenarios are plausible, but unverifiable accounts that represent a process of change over some time frame; they show what could be, not what will happen or what should be. Scenario planning is a systematic method for thinking about complex and uncertain futures, which considers a variety of possible futures that include important uncertainties of the system rather than focusing on the accurate prediction of a single outcome (Peterson et al. 2003). Generally, scenarios organize information within explicitly defined frameworks. Working through the

We face a fundamental challenge in conservation planning, because there is a critical mismatch between the scales at which we should think and the scales in which we act in both time and space.

We need to "close the loop" after a land use decision is made. That is, we need to complete the full cycle of making land use decisions, monitoring the status and trends of land use change (nationally, regionally, and locally), evaluating and assessing those changes, and then adapting our policies accordingly.

process of explicitly defining a scenario often leads decision-makers to consider implications that might have been missed otherwise. This will not only allow decisions to be based on what has happened in the past, but also expose possible unanticipated "surprises" that may occur. Finally, scenarios facilitate and coordinate discussion among stakeholders that may not have otherwise constructively engaged in the process.

Build-out analysis is an important means of providing useful information to stakeholders, and GIS-based tools are emerging that facilitate conducting a build-out analysis. An early innovator was Lacy (1992). Theobald and Hobbs (2002) used build-out analysis to examine the likely effects of different policies on important wildlife values in Summit County, Colorado. Another example is the Center for Rural Studies at the University of Vermont (Sawyer et al. 2005).

Assist in collection of biological data on private lands

There are often poor data on biological resources for privately-owned land. Land use planners and decision makers can assist in the collection of data by helping design, facilitate, and support long-term monitoring of the effects of land use change.

What practices would help convey science-based information to land use planners?

Close the loop: Plan, monitor, evaluate, adjust

We need to "close the loop" after a land use decision is made. That is, we need to complete the full cycle of making land use decisions, monitoring the status and trends of land use change (nationally, regionally, and locally), evaluating and assessing those changes, and then adapting our policies accordingly. Commonly land use decisions are made singly (e.g., in development review) and are often embroiled in conflict. Rarely is evaluation of patterns and trends incorporated into planning, and when it is, it is limited because the feedback cycle is too slow (e.g., 10-20 year master planning cycle) and is often triggered by a precipitating event. Instead, the full cycle (planning, monitoring, evaluating, and adjusting) should be completed on an annual to semi-annual basis. Even if a more adaptive learning approach is achieved, however, a significant challenge will remain, namely that citizens engaged in planning typically want predictability rather than flexibility (Theobald et al. 2000).

Two types of activities could be tapped into and refined to serve as a starting place for incorporating adaptive management into conservation planning. First, a number of efforts have emerged to generate *scorecards* to evaluate the status and trend of a community (e.g., EPA's Smart Growth Scorecards, http://www.epa.gov/smartgrowth/scorecards/). These are useful for providing a structured evaluation of how well things are being planned for. Yet, from the perspective of biodiversity conservation, they tend to be too general and fairly limited in conservation assessments.

For example, the Colorado Scorecard has ten different sections, only one of which deals explicitly with natural resources and biodiversity (called "Natural Capital"). Only general, qualitative questions are asked. There is little or no landscape context, and no explicit biodiversity values. The general idea is reasonable, but further refinements are needed. Some suggestions for improvement would be to:

- compute the rate and pattern of land use change (parcel by parcel) on a monthly to yearly basis;
- compute what societal values (indicators) have been negatively affected or conserved;
- compute the amount of conserved land over time, and discern different societal values being protected and the landscape context (isolated, buffer, infill, corridor, etc.).

A second activity is the US Green Building Council's *LEED neighborhood development* rating system (USGBC 2005), which could provide a useful model on which to build an adaptive decision-making process. It has been at least forty years since William Whyte (1964) first raised awareness about the connection between the loss of habitat and the design of subdivisions, and more recently Arendt's work on conservation subdivision design (2004) has contributed to the discussion as well. An important need will be to develop indicators of impact or conservation results that will be meaningful to citizens and decision-makers.

Conservation Planning Tools

There is a growing number of conservation planning tools that can be used to help land use planners carry out science-based planning for biodiversity conservation. Nearly all of these decision-support systems use geographic data about conservation targets and protected areas, so they typically are built on a geographic information system (GIS) platform. These can range from efforts that serve spatial data over the internet (e.g., the Colorado Natural Diversity Information Source), to custom applications focused on specific planning issues (e.g., CommunityViz.com, NatureServe's Vista), to general tools that can be used by a conservation planner (e.g., FRAGSTATS, McGarigal and Marks 1995, LINK, Fox et al. 2003, FunConn, Theobald et al. 2006).

The rapid and widespread development of GIS-based tools and analyses is encouraging, but we should temper our excitement a bit. Like other tools, they can be used improperly or misused — most commonly by employing poor data, using implicit and arbitrary values, and conducting analyses at the wrong scale (Stokes and Morrison 2003). Below are some additional challenges and recommendations for conservation planners when conducting GIS-based analyses:

- the spatial grain of data needs to match the way that a species or process scales its environment, including data on vegetation/land cover, human activities (including economic activities), and protected areas (Theobald et al. 2005);
- a set of standardized indicators are needed that are peer-reviewed and sensitive to fine-scale land use changes such as a house footprint, small wetlands and riparian zones, etc.;
- models should be flexible enough to allow users to incorporate local-scale knowledge of habitat and to examine ranking of important habitat changes;
- approaches to integrate indices of individual (fine-filter) species or conservation targets and community-level (coarse-filter) targets into landscape planning are needed (e.g., Opdam et al. 2003);
- measures of threats associated with transportation should differentiate the presence (e.g., road density) from the level of use (e.g., road traffic volume);
- differentiate first-order neighborhood measures from full-landscape configuration metrics; and
- mapping corridors and measuring connectivity should incorporate a functional connectivity perspective (Crooks and Sanjayan 2006, Hilty et al. 2006).

Conclusions

I'd like to conclude this essay by revisiting a few key lessons learned from direct experience working at the interface of conservation and planning. In 1994, we initiated a project called the System for Conservation Planning – the objective of the project was to "produce an information system that assembled data and analyses on wildlife populations and habitats and that made those data readily accessible over the World Wide Web" (Theobald et al. 2000, p. 36). This project continues today, slightly changed, as the Colorado Natural Diversity Information Source (www.ndis.nrel.colostate.edu). Some key insights from that work include:

- *Simple is better:* Models are a common way to bridge scientific principles and implementation, but to be useful, they should be as simple as possible — for stakeholders to understand. As the diversity of issues and/or the variety of places that are addressed by these models expands, models tend to become increasingly complicated. Simple models will also be likely more transferable to other situations and locales.
- *It's "support," not "supplant":* The premise here is to have better conservation data and analysis to inform and support decision-making. Decision-support systems, powered typically by GIS, are commonly developed to enhance decision-making by synthesizing a variety of spatial datasets in a useful way. But these systems need to add value, not replace existing methods. Although web-based technologies are very useful, do not let technology drive the design of a decision-support system.
- *Experts are still needed:* The science of biodiversity conservation is, and will likely remain, complex enough that expert interpretation is needed to bridge the gap between general scientific principles and their on-the-ground implementation in a land use plan. Information can be disseminated more easily and widely, but there will remain a need for biodiversity experts and planners to help collect, interpret, and communicate that information for citizens and decision-makers.

The science of biodiversity conservation is, and will likely remain, complex enough that expert interpretation is needed to bridge the gap between general scientific principles and their on-the-ground implementation in a land use plan.

- *People hold values:* Making land use decisions requires value-based judgments to be made, so planning processes should facilitate elicitation, discussion, and codification of conservation values to a given community (e.g., what species are of interest, to whom?).
- *Political will is fleeting.* Political will is strongest when there is long-term knowledge and interest of the citizens engaged in a planning process. Yet decision-makers at nearly all levels tend to have a short professional lifespan, serving typically for two to three years. Transitions among professional planning staff can impede the construction and incorporation of "corporate" knowledge, while the interest level of citizens quickly rises and falls with particularly divisive planning issues, and engaged citizens (stakeholders) fatigue fairly quickly. A corollary to this is that "champions" in the community are also needed to maintain consistency and to establish the legitimacy of a project. This is one of the greatest impediments to integrating biodiversity information into planning (Cohn and Lerner 2003).
- *Collaborate.* Conservation planning requires a diversity of expertise and viewpoints because it deals with the dynamics of natural and human systems, embedded in a context characterized by landscapes, ecological processes, political realities, cultural norms, and human values. Hobbs (1999) offers some practical "habits" for successful collaboration between conservation biologists and planners, including:
    - Communicate that there is no single, scientific "truth" for complex environmental problems;
    - Insist that analytical procedures must be understood by everyone who is affected by them;
    - Be willing to use rules of thumb that someday may prove to be false; and
    - Recognize that many of your collaborators have day jobs.

Planning is the most important way we as citizens and scientists can affect our community, our quality of life. And conservation planning is urgently needed to conserve the world's biodiversity. Let's not take what we have for granted.

Literature Cited

Arendt, R. 2004. Linked landscapes: creating greenway corridors through conservation subdivision design strategies in the northeastern and central United States. *Landscape and Urban Planning.* 68: 241-269.

Batty, M. 1997. Cellular automata and urban form: a primer. *Journal of the American Planning Association*. 63: 266-274.

Benedict, M.A. and E.T. McMahon. 2001. *Green Infrastructure: Smart Conservation for the 21st Century*. Sprawl Watch Clearinghouse Monograph Series.

Bradshaw, T.K. and B. Muller. 1998. Impacts of rapid urban growth on farmland conversion. *Rural Sociology*. 63: 1-25.

Clark, T.W. 2002. *The Policy Process: A Practical Guide for Natural Resources Professionals*. New Haven, CT: Yale University Press.

Clarke, K.C., L. Gaydos, and S. Hoppen. 1997. A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area. *Environment and Planning B*. 24: 247-261.

Cohn, J.P. and J.A. Lerner. 2003. *Integrating Land Use Planning and Biodiversity*. Washington, D.C.: Defenders of Wildlife.

Crooks, K.R. and M.A. Sanjayan (eds.). 2006. *Connectivity Conservation: Maintaining Connections for Nature*. Cambridge: Cambridge University Press.

Csuti, B. and P. Crist. 2000. *Mapping and Categorizing Land Stewardship*. Version 2.1.0. A handbook for conducting gap analysis. Moscow: University of Idaho.

Davey, A.G. (ed.) 1998. *National System Planning for Protected Areas*. Gland, Switzerland: IUCN.

Duerkson, C.J., Hobbs, N.T., Elliott, D.L., Johnson, E., and Miller, J.R. 1996. *Managing Development for People and Wildlife: A Handbook for Habitat Protection by Local governments*. Chicago, IL: American Planning Association, PAS #470/471.

Ernst, T.L., K.M. King, K.M. and G.W. Wallace. 2006. *An Integrated Analysis of Private Land Conservation in Larimer County, Colorado: The Entities and Landowners Involved and the Benefits Being Produced*. Unpublished report, Colorado State University.

Fox, T.J., J.J. Rohweder, K.P. Kenow, C.E. Korschgen, and H.C. DeHaan. 2003. "Geographic information system tools for conservation planning: user's manual." U.S. Geological Survey, Biological Resources Discipline Information and Technology Report USGS/BRD/ITR-2003-0005.

Fraterrigo, J.M. and J.A. Wiens. 2005. Bird communities of the Colorado Rocky Mountains along a gradient of exurban development. *Landscape and Urban Planning*. 71: 263-275.

Fulton, W., R. Pendall, M. Nguyen, and A. Harrison. 2001. *Who Sprawls Most? How Growth Patterns Differ Across the U.S.* The Brookings Institution, Survey Series. July. http://www.brookings.edu/es/urban/publications/fulton.pdf (Accessed February 28, 2007.)

Hansen, A.J., R. Rasker, B. Maxwell, J.J. Rotella, J.D. Johnson, A.W. Parmenter, U. Langner, W.B. Cohen, R.L. Lawrence, and M.P.V. Kraska. 2002. Ecological causes and consequences of demographic change in the New West. *BioScience*. 52(2): 151-162.

Hansen, A.J., R.L. Knight, J.M. Marzluff, S. Powell, K. Brown, P.H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications*. 15(6): 1893-1905.

Hilty, J.A., W.Z. Lidicker, and A.M. Merenlender. 2006. *Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation*. Washington, D.C.: Island Press.

Hobbs, N.T. 1999. Seven habits for successful collaboration with local governments. *Society for Conservation Biology Newsletter*. 6(4): 1-2.

IUCN. 1994. *Guidelines for Protected Areas Management Categories*. Cambridge, UK and Gland, Switzerland: IUCN.

IUCN-CMP (Conservation Measures Partnership) 2006. "Unified Classification of Conservation Actions, Version 1.0." http://conservationmeasures.org/CMP/IUCN/Site_Page.cfm. (Accessed February 27, 2007.)

Kahn, A.E. 1966. The tyranny of small decisions: Market failures, imperfections, and the limits of economics. *KYKLOS*. 19: 23-45.

Kahn, H. and A.J. Weiner. 1967. *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years*. New York: MacMillan.

Lacy, J. 1992. *Manual of Build-Out Analysis*. Center for Rural Massachusetts.

Land Trust Alliance (LTA). 2006. *2005 National Land Trust Census*. Washington, D.C.: Land Trust Alliance.

Lenth, B.A., R. L. Knight, and W. C. Gilgert. 2006. Conservation value of clustered housing developments. *Conservation Biology*. 20(5): 1445-1456.

Lerner, J, B. Cochran, and J. Michalak. 2006. *Conservation Across the Landscape: a Review of the State Wildlife Action Plans*. Washington, D.C.: Defenders of Wildlife.

Maestes, J., R.L. Knight, W.C. Gilgert. 2003. Biodiversity across a rural land-use gradient. *Conservation Biology*. 17(5): 1425-1434.

Manfredo, M.J., and P. Brown. 2004. The growth of a human dimensions perspective in park and protected area management. Paper presented at the IV Congresso Brasiliero de Unidades de Conservaco.

Mascia, M.B., J.P. Brosius, T.A. Dobson, B.C. Forbes, L.Horowitz, M.A. McKean, and N.J. Turner. 2003. Conservation and the social sciences. *Conservation Biology*. 17(3): 649-650.

McGarigal, K. and B.J. Marks. 1995. *FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure*. USA Forest Service General Technical Report PNW-351.

Merenlender, A.M., L. Huntsinger, G. Guthey, and S.K. Fairfax. 2004. Land trusts and conservation easements: Who is conserving what for whom? *Conservation Biology*. 18(1):65-75.

Noss, R.F., M.A. O'Connell, and D.D. Murphy. 1997. *The Science of Conservation Planning*. Washington, D.C.: Island Press.

Odell, E.A., D.M. Theobald, and R.L. Knight. 2003. Incorporating ecology into land use planning: The songbird's case for cluster development. *Journal of American Planning Association*. 69(1):72-81.

Odum, W.E. 1982. Environmental degradation and the tyranny of small decisions. *BioScience*. 32:728–729.

Opdam, P., J. Verboom, and R. Pouwels. 2003. Landscape cohesion: an index for the conservation potential of landscapes for biodiversity. *Landscape Ecology*. 18: 113-126.

Pejchar, L., P.M. Morgan, M.R. Caldwell, C. Palmer, and G.C. Daily. (2007). Evaluating the potential for conservation development: Biophysical, economic, and institutional perspectives. *Conservation Biology*. 21(1): 69-78.

Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology*. 17(2): 358-366.

Sawyer, W., K. Behm, and C.L. Davis. 2005. "Community build-out analysis v2.0." Center for Rural Studies, University of Vermont. http://crs.uvm.edu/cpdp/buildout. (Accessed February 27, 2007.)

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, Jr., J. Ullman, and G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs*. 123:1-41.

Steinitz, C., M. Binford, P. Cote, T. Edwards Jr., S. Ervin, R.T. T. Forman, C. Johnson, R. Kiester, D. Olson, A. Shearer, R. Toth, and R. Wills. 1996. *Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California*. Cambridge: Harvard University Graduate School of Design.

Stokes, D. and P. Morrison. 2003. GIS-based conservation planning: a powerful tool to be used with caution. *Conservation In Practice*. 4(1).

Theobald, D.M., J.M. Miller and N.T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. *Landscape and Urban Planning*. 39(1): 25-36.

Theobald, D.M., N.T. Hobbs, T. Bearly, J. Zack, T. Shenk, and W.E. Riebsame. 2000. Incorporating biological information into local land-use decision making: Designing a system for conservation planning. *Landscape Ecology*. 15(1): 35-45.

Theobald, D.M. 2001. Land use dynamics beyond the American urban fringe. *Geographical Review*. 91(3):544-564.

Theobald, D.M. and N.T. Hobbs. 2002. A framework for evaluating land use planning alternatives: Protecting biodiversity on private land. *Conservation Ecology*. 6(1): 5. http://www.ecologyandsociety.org/vol6/iss1/art5. (Accessed February 27, 2007.)

Theobald, D.M. 2003. Targeting conservation action through assessment of protection and exurban threats. *Conservation Biology*. 17(6):1624-1637.

Theobald, D.M. 2004. Placing exurban land use change in a human modification framework. *Frontiers in Ecology and Environment*. 2(3):139-144.

Theobald, D.M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. *Ecology and Society*. 10(1): 32. http://www.ecologyandsociety.org/vol10/iss1/art32/. (Accessed February 27, 2007.)

Theobald, D.M., T. Spies, J. Kline, B. Maxwell, N.T. Hobbs, and V.H. Dale. 2005. Ecological support for rural land-use planning. *Ecological Applications*. 15(6): 1906-1914.

Theobald, D.M., J.B. Norman, and M.R. Sherburne. 2006. *FunConn v1 User's Manual: ArcGIS tools for Functional Connectivity Modeling*. Natural Resource Ecology Lab, Colorado State University. www.nrel.colostate.edu/projects/starmap. (Accessed February 27, 2007.)

US Green Building Council (USGBC). 2007. *LEED for Neighborhood developments rating system pilot version*. US Green Building Council https://www.usgbc.org/ShowFile.aspx?DocumentID=2310 (Accessed February 27, 2007.)

Whyte, W. 1964. *Cluster development*. New York, New York: American Conservation Association.

Protecting Wildlands Beyond the Urban Fringe

Adina Merenlender, Ph.D., University of California, Berkeley

Introduction

Land use change is the primary driver of habitat loss and ecosystem degradation, and greatly intensifies other threats to the environment (Harte 2001). Habitat loss and fragmentation are leading to an unprecedented rate of species extinction, which heightens the importance of conservation planning to protect biodiversity and the need to increase the efficiency of land and water use for a growing population.

Much conservation planning in the United States is focused on the recovery of endangered species. This is because the Endangered Species Act, one of the most powerful environmental laws passed by Congress, makes the “take” of listed species illegal. The planning required for endangered species recovery has led to innovations in protected area planning, and has helped address the gradual loss and fragmentation of wildlands (McCaull 1994). However, endangered species recovery plans are limited to certain areas of the country, and this process is well-described and has been evaluated in existing literature (Kareiva et al. 1999).

In the majority of cases, land use and land conservation decisions are made at the local level. For example, land use policies such as zoning, transfer of development rights, and urban growth limits are used by local governments to minimize loss of natural habitat and agricultural land. Absent compensation, the level of protection that can be expected from local land use regulations is influenced by the extent to which regulations limit the current or future economic returns to private landowners.

The use of incentive-based conservation programs has greatly increased over the past twenty years, in part as a backlash to local land use regulations that limit the use of private lands and their associated resources (Merenlender et al. 2004). Thus, purchasing partial or full interest in land has become a very important tool for protecting private land resources. According to the Trust for Public Land (2005), between 1994 and 2006 voters approved 1,299 land protection initiatives that authorized $31 billion in conservation funding. Such incentive-based land conservation has resulted in an explosion of the land trust movement in the United States and elsewhere. Private trusts and public agencies are involved in these acquisition programs for private land conservation, and have had to invest in conservation planning in order to maximize the returns on their investments.

As a result, these institutions have in some cases been leaders in implementing conservation science for planning purposes (Stoms et al. 2005). The literature on targeting land conservation for private and public organizations involved in acquisition and compensation programs is well-developed (Zbinden and Lee 2005, Newburn et al. 2005, Wilson et al. 2006). Despite the importance of such protected area planning, this essay is not focused entirely on it; though I do discuss the need to improve the way we estimate the relative value of natural areas to include the multiple conservation benefits they may provide. I also avoid dealing explicitly with the general principles of conservation biology that should be extended to planners, such as habitat loss, fragmentation, and restoring connectivity. These, while also still in need of increased understanding, are well-developed in books and journal articles, and have already been translated to the public by earlier efforts (Hilty et al. 2006a, Environmental Law Institute 2003).

Instead, I explore several scientific hurdles that need additional research, in order to better advise city and county land use planners who are faced with multiple, and in some cases conflicting, objectives to ensure the protection of social and environmental amenities. These include: 1) addressing multiple environmental benefits that need protection to maintain and restore natural ecosystems and their associated goods and services; 2) quantifying non-linear cumulative impacts of land use change and thresholds beyond which we observe environmental degradation; 3) exploring patterns, processes, and consequences of low-density development; and 4) stressing the importance of outcomes research so we can evaluate the effectiveness and unintended consequences of policies that are currently used by land use planners to control sprawl. My recommendations to local planners are focused on collaborative regional planning to slow the spread of low-density development, which is having an unprecedented impact on wildland fragmentation, and stress the importance of taking a more adaptive approach to land-use planning.

My recommendations to local planners are focused on collaborative regional planning to slow the spread of low-density development and stress the importance of taking a more adaptive approach to land-use planning.

It is very difficult to effectively implement science-based conservation planning, because success is measured by whether people change the way they do business in response to learning about scientific findings. It is much easier for scientists to teach college students and to publish in the scientific literature than it is to change the way planners, land owners, and resource managers do their work, or how decision-makers view an issue and the potential solutions. Based on my experience working with planners at the local level, I propose ways that science-based information might be more effectively integrated into the practice of land-use planning.

What are the major gaps in the conservation biology research agenda that need to be filled to improve land use and conservation planning?

In general, we need to better couple land conservation efforts for biodiversity protection with land-use planning. Below are three areas where research is needed to better inform both land-use and land conservation decision making. These include: increasing our understanding of low-density exurban residential development patterns and their consequences for animal and plant communities; addressing how to prioritize multiple environmental benefits that are in need of protection; and quantifying the cumulative effects of land use to better inform planners about the environmental and social trade-offs of their decisions.

Patterns, processes, and consequences of exurban development

Exurbia, defined as low-density residential development outside of urban services boundaries, is now the fastest-growing type of land use in the United States (Theobald 2001). This development is different than the dense suburban development that commonly occurred in the United States between 1960 and 1990. Exurban development results in an unorganized scattering of homes on large parcels of land (one unit per 4-16 hectare or 10-40 acre parcel). These developments typically rely on private water wells and individual sewage systems, and are located along rural roads without street lights (Theobald 2001). Heimlich and Anderson (2001) estimate that nearly 80 percent of the acreage used for new housing construction in 1994-1997 was on lots larger than one acre, and 57 percent was built on lots ten acres or larger. This type of development now takes up fifteen times the area of higher-density development (Brown et al. 2005). Estimates based on nighttime satellite imagery suggest that 37 percent of the U.S. population now lives in exurban areas that account for 14 percent of the land area. In contrast, urban and suburban development house 55 percent of the population and account for only 1.7 percent of the land area.

A well-documented example of the type of fragmentation that can result from exurban development was the Sierra foothills of California (Walker and Fortmann 2003). Here, the median size of landholdings in 1957 for Nevada County was 223 hectares, but by 2001 it had been reduced to just 3.6 hectares. The impacts of this type of fragmentation on biodiversity are generally unknown, and likely to be undervalued (Harte 2001) given the comparatively larger amount of research focused on urban ecology.

Due to the extent of this problem, there has been a call for increased focus on ecological principles in land-use planning and for sprawl-limiting policies to address the issues associated with what is sometimes termed the wildland-urban interface (Radeloff et al. 2005). Others have argued for further studies on the impacts to species conservation, and suggest an extinction debt (the time lag between disturbance and when species extinctions are observed) that remains to be paid resulting from the relatively recent expansion of exurban development (Hansen et al. 2005). Because of the severe consequences associated with this expanding type of land-use, much of this essay considers issues surrounding low-density development beyond the urban fringe.

Very little is known about what determines the extent and pattern of exurban development, and this lack of understanding makes it difficult to pose solutions to the problem. The growth in rural residential development comes from factors that “push” residents towards these areas, such as low housing supply and higher costs associated with city dwellings and the urban fringe; as well as “pull” factors, such as attractive scenery and quiet country living (Heimlich and Anderson 2001). In many places exurban residents view the natural environment as an important amenity (Crump 2003). One survey showed that 45 percent of Americans living in medium-to-large cities wanted to live in a rural or small-town setting 30 or more miles from the city (Brown et al. 1997). But the exact attractants for this type of development are relatively undocumented, and the resulting patterns are not sufficiently quantified. This is in part due to the inherent difficulties in mapping and monitoring this type of development remotely – making useful information generally unavailable (but see Sutton 2006).

More information is needed on exurban development patterns to better evaluate the extent to which privately owned wildlands are in fact highly modified by low-density development. Unfortunately, mapping low-density residential development often requires local parcel and assessor's data that is not always available digitally, and that can be time consuming to acquire over a large area. Furthermore, surveys of people living in exurbia are needed to identify the exact attractants that lure them to live in the countryside as well as factors that may push them toward remote locations. This information will help increase our understanding of the process and pattern of exurban development, which is needed to better address the problem through policies, regulations, and incentive programs.

Conservation biologists are only beginning to address the consequences of low-density development for habitat loss, fragmentation, and biodiversity. Much of the work has focused on the response of bird communities to residential development, and demonstrated that only certain species tolerate houses and their associated disturbances (Nillon et al. 1995, Reynaud and Thioulouse 2000, Parsons et al. 2003, Odell et al. 2003, Manley et al. 2006). In California's oak woodlands, low-density residential development proves as unsuitable for some bird species as are suburban neighborhoods where urban adapted species dominate (Merenlender et al. 1998). Also, Odell and Knight (2001) found that mesocarnivore densities were affected up to 300 meters from residential developments, and that differences in wildlife densities in areas of low and high development density were insignificant. These results are cause for concern, given the increasing amount and large geographic extent of exurban development. More research is needed on wildlife abundance along land use gradients that explicitly include areas of low-density development.

Additional research is also needed on how the distribution of invasive species is associated with the degree of fragmentation and connectivity of the landscape (With 2002). The synergy between spatial patterns of disturbance and the spread of invasives may be especially important in areas of high biodiversity that are undergoing rapid anthropogenic change (Abbitt et al. 2000, Hilty et al. 2006b). In particular, the extent and pattern of exurban and other land use modifications influences the probability of exotic species invasions. For example, rural residential development was associated with invasion by exotic plant species around Lake Tahoe, California; and these sites are potentially serving as staging areas for dispersal of those species into less fragmented lower montane forests (Manley et al. 2006). Also, if there exist disturbance thresholds beyond which invasions by non-natives are more likely, then quantifying these could help land-use planners and managers reduce such risks.

Targeting multiple environmental benefits for conservation planning

As discussed earlier, the literature dedicated to protected area planning is well-developed. Research and models designed to help decision-makers prioritize land conservation goals makes up most of what is understood as systematic conservation planning (Margules and Pressey 2000). The most important components of protected-area planning models are the distributions of biological or other conservation benefits, economic costs of the required conservation action, and the probability that the site will be lost if no action is taken. Most recently, experts in the field have advocated for minimizing the future loss of species and habitat by integrating threats from land use into protected-area planning algorithms. It is also important to integrate the cost of removing that threat through full or partial purchase of land iteratively when optimizing private land protection; and both the threat and the cost need to be considered over time in order to prioritize acquisition correctly over the long-term (Wilson et al. 2006, Newburn et al. 2005, Meir et al. 2004, Costello and Polasky 2004).

More information is needed on exurban development patterns to better evaluate the extent to which privately owned wildlands are in fact highly modified by low-density development.

There are ways to sort through tens of thousands of parcels and consider changing probabilities of each parcel being converted, as well as the relative costs of acquiring each parcel (Newburn et al. 2006) for targeting purposes. The importance of quantifying the relative threat to habitat and its associated natural resources cannot be overstated (see Figure 1 for an example of a parcel-level threat map). This is essential in order to ensure that we are prioritizing land that needs protection rather than what is more commonly done, which is to maximize investors' returns by purchasing full or partial interests in inexpensive land that is often not in need of immediate protection, thereby allowing higher-priority sites to be lost to development or resource extraction. This means that conservation science needs to do a better job at modeling the built environment and transforming these models into decision-support tools for conservation planning.

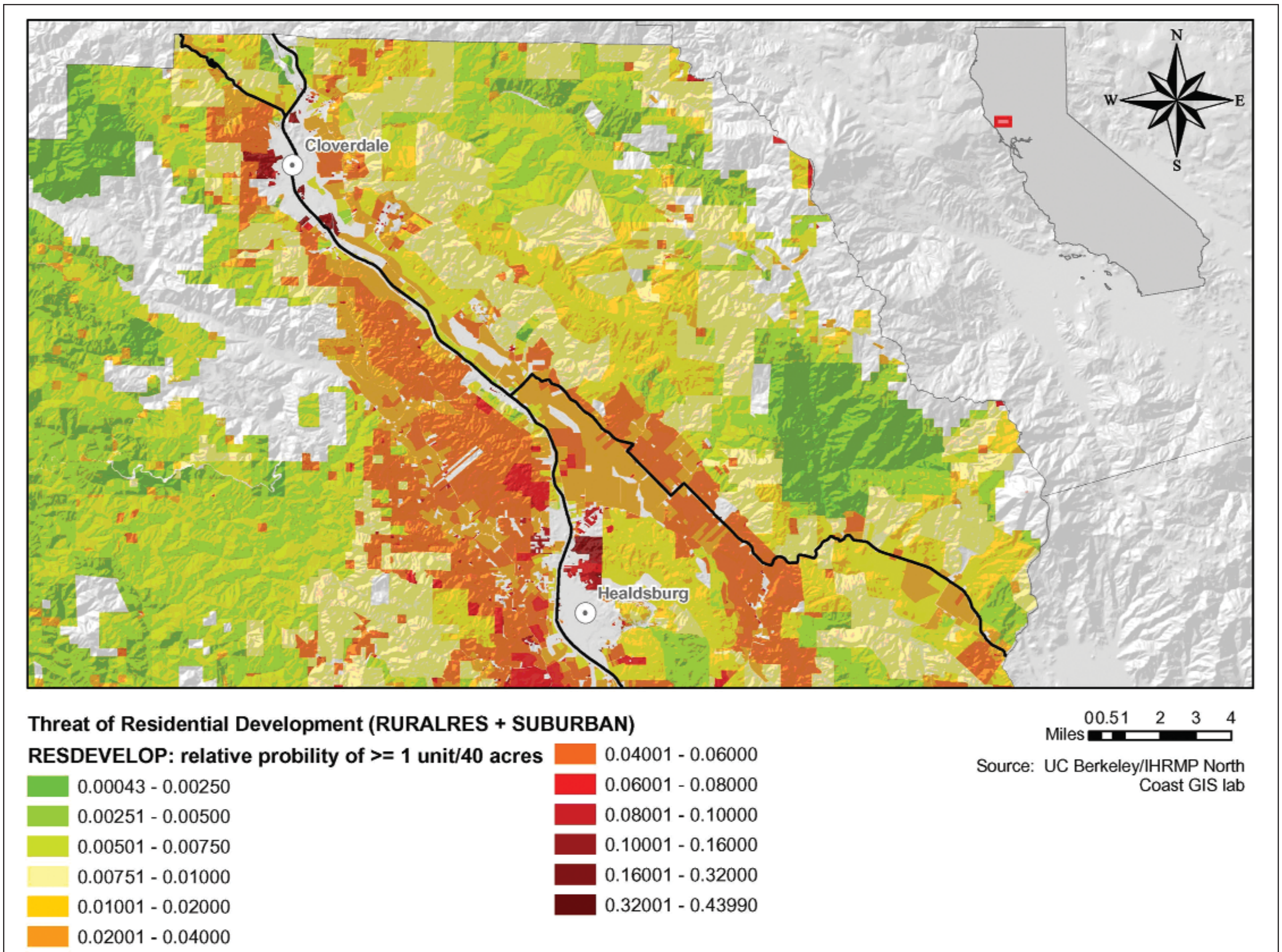

FIGURE 1. Example of a parcel-level threat model for low-density residential development outside the city of Cloverdale and Healdsburg, Sonoma County, California (see Newburn and Berck 2006 for modeling details).

While more attention is needed to refine our threat and cost models, we also are often missing information on the distribution of ecological benefits that need conservation, and information on how much land, of what types, quality, and patch size is required to effectively protect biological benefits such as endemic species and habitat. This is particularly difficult when multiple conservation objectives, such as several different species, habitat types, and services, are in need of protection. This is a key issue because most incentive-based conservation programs have multiple desired outcomes such as wetland protection, water quality, and endangered species conservation. Thus, one of our greatest challenges is to help ensure that the money spent on these programs optimizes the returns for multiple environmental benefits. Many conservation scientists working with economists have resorted to relating environmental benefits to a common monetary currency, which solves the problem if and only if the benefits can be quantified in financial terms (monetized) – which is often not the case.

Three examples of theoretical benefit functions are shown in Figure 2; the shape of these curves determines how much land is needed to secure a sufficient proportion of a particular conservation benefit. Since the actual shape of these functions is rarely known, it is difficult to determine the precise extent of land protection needed. This challenge is compounded by the fact that the pattern and configuration of a protected area network influences benefit functions in ways we rarely understand. Based on basic principles of conservation biology, we know that the benefits from one site depend on the type and protection status of neighboring sites, and that nonlinear increases in benefits can result from increased protection of adjacent land – complicating matters greatly. Therefore more work is needed on the value of connectivity among protected areas.

Biological resources are often not fungible (countable and interchangeable), and therefore it may be impossible to evaluate the tradeoff between conserving one type of habitat and another, just as we can't compare apples and oranges (Williams and Araujo 2002). These problems are illustrated when we think about trying to conserve mature forests for spotted owl habitat along with open wetlands that support their prey. We don't necessarily understand the amount of mature forest required to support the owls and maintain resistance to invasion of competing barn owls; mature forests generally do not overlap with open wetlands; and prey availability varies dramatically due to fluctuations in rodent population sizes, making the amount of prey habitat required difficult to predict.

In practice, protected-area plans are typically determined by regional goals and *ad hoc* scoring procedures, and site ranking depends on the choice of relative weights within and between benefit types. Setting regional conservation targets such as a certain percent of habitat, which is commonly done to meet international conservation goals, is another way of weighting and comparing habitat types. In this approach, the relative measure of irreplaceability or complementarity depends on the differing extent of remnant habitat and how this compares with stated targets, usually based on estimates of historic vegetation coverage. For example, if only a small percentage of historic levels of wetland or tropical forest exist

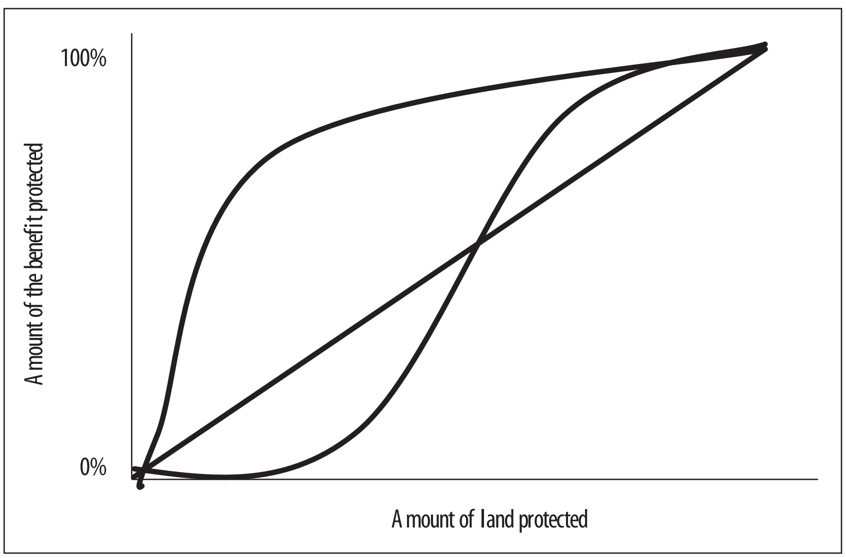

FIGURE 2. The top line is a theoretical representation of a conservation benefit (e.g. species, habitat or open-space element) that is secured with very little land protected, the straight line represents a resource whose protection is incrementally improved at the same rate with each added amount of land protected, and the s-shaped curve demonstrates a threshold effect, beyond which a certain amount of land secures the entire resource with little benefit of additional acquisition past the threshold point. Examples of the first could be a small vernal pool of endemic fairy shrimp; California's coastal salmon populations may behave more like the straight line; and a greenbelt or community separator would behave like the s-shaped curve.

today, then recovering enough to meet a target of 10% of the former extent will weight this rarer habitat type over a less impacted habitat type.

The sensitivity of ranking which sites ultimately get selected for conservation will depend fundamentally on the correlation and relative variation among the benefit functions. Positive correlation signifies co-occurrence of the priority species or habitats, whereas negative correlation indicates that the two distributions rarely overlap. If the biological benefit function were redefined to differentially weight one type in comparison to another – thus increasing the ratio of weights between the two distinct habitat types — the resulting set of priority sites would include more parcels from one habitat type at the expense of the other. This substitution effect of site selection increases with the strength of negative correlation among multiple distributions of benefit types. This may result in a see-saw effect, where site rankings shift primarily as a function of the relative weights, which are usually defined with very little objective scientific basis (Newburn et al. 2005).

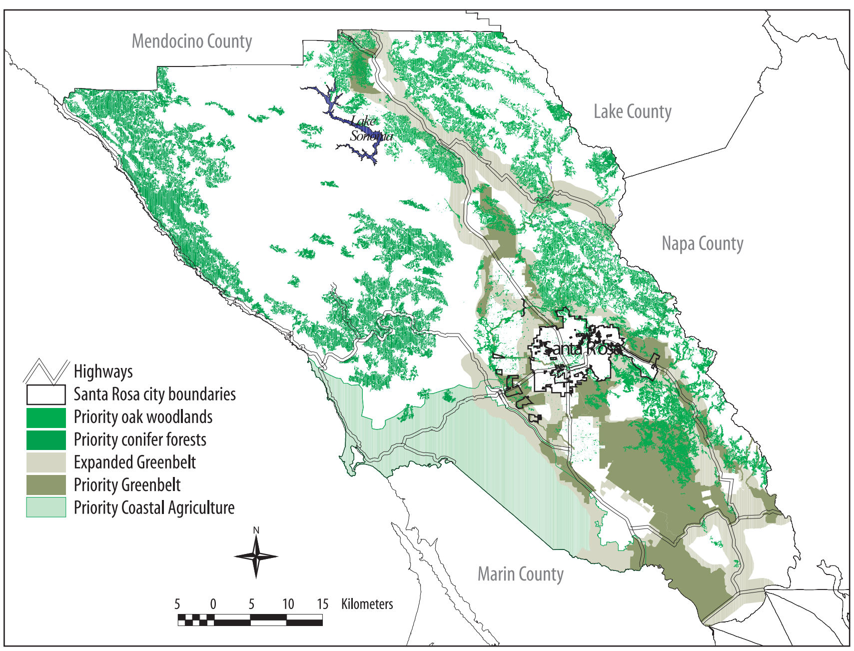

FIGURE 3. This map demonstrates very little spatial overlap in the priority conservation benefits identified by the Sonoma County Agricultural Preservation and Open Space District. So targeting at the parcel level is done separately for each resource listed in the legend, rather than weighting or summing uncorrelated resources together.

To avoid this, multiple benefits must be decoupled in the prioritization process when they are uncorrelated in space. In other words, apples and oranges should not be pooled together and given a relative weight prior to selecting which lands to protect; rather sites should be selected to ensure the protection of one and then the other independently. Or example, in Sonoma County, California, natural resources such as oak woodlands, conifer-dominated forestlands, and greenbelts are not correlated in space, and therefore parcels supporting these resources had to be prioritized separately for acquisition by the Sonoma County Agricultural Preservation and Open Space District (Figure 3). Unfortunately, although this solution avoids erroneous results, it does not allow for the most efficient targeting of multiple benefits that will minimize the costs of protecting the many natural resources in need of protection.

We need to recognize that even with the best available data, the benefit functions assumed and their relative weightings are products of their particular social, economic, and political contexts (Newburn et al. 2005). A planner or decision-maker unfamiliar with the optimization algorithms may not clearly see how differences among spatial data on benefit distributions and relative weights of model inputs can dramatically influence the optimal solutions produced. It is critical that conservation scientists and economists continue to address how best to combine the values of multiple environmental benefits in order to set thresholds and prioritize land conservation.

Cumulative impacts, non-linear thresholds, and marginal gains

Planners work toward protecting environmental quality through the construction of sustainable development plans, and by overseeing environmental review of specific development projects. In California and at least eighteen other states, individual projects are reviewed under state environmental quality laws and policies that hinge primarily on an environmental impact report. Environmental review usually takes place at the project or regional scale in order to balance protection of the environment and quality of life with the need for economic growth. As part of this process, the cumulative effects of the project in relation to past, present, and foreseeable future projects in the surrounding area must be assessed. Understandably, then, land use planners are requesting research to identify cumulative effects and the thresholds beyond which they might occur to justify restrictions on development (Environmental Law Institute 2003, Huggett 2005).

Predicting how ecosystems will respond to proposed current and future development requires an understanding of ecosystem resilience — the amount of disturbance that an ecosystem can withstand without changing its self-organizing processes and the variables that control its structures (Holling and Gunderson 2002). There is mounting evidence that resilience is reduced in response to human-induced disturbance that results in reducing biological diversity, removing assemblages of species or entire trophic levels, changing the climate, polluting the ecosystems, and altering the frequencies and duration of disturbance (Folke et al. 2004). In response to these changes, ecosystems can become brittle, and suddenly shift to undesirable states that reduce their capacity to provide desired goods and services (Scheffer et al. 2001).

A well-known example of this is Wisconsin's Lake Mendota, which had received a steady influx of nutrients from surrounding farms and developed areas for years without any dramatic change. Then suddenly, following a large rain event in 1993, Lake Mendota displayed a large increase in algal growth and became eutrophic. It turns out that phosphorus buildup in the mud for years prior to this storm event had decreased the lake's resilience, and ultimately resulted in a sudden ecosystem state change that greatly impacted water quality and the fishery (Bennett et al. 1999). It is highly desirable to prevent these sometimes disastrous transitions and, where possible, attempt to restore ecosystems so that they can continue to function. To encourage planners to maintain resilience, we need to better understand the interactions between human and natural systems, and how disturbance influences ecosystem resilience and biodiversity conservation.

There is mounting evidence of threshold effects resulting from human perturbations to ecosystems (Muradian 2001). For managers and planners, there is a strong desire to know at what particular point the level of disturbance crosses a threshold — leading the organizing processes of the system to change from one state to an alternative, potentially more degraded state (Carpenter et al. 2001). Ecosystems often display non-linear responses to stressors (Donohue et al. 2006, Phillips 2006), which means that changes between one environmental state and a more degraded state may happen suddenly, rather than as a gradual response to increased disturbance. To predict the response of ecosystems to disturbance thus often requires the use of non-linear models and extensive data on the response variable across time and space. The importance of dealing with non-linear dynamics of ecological systems and existing thresholds is widely recognized (Muradian 2001).

The use of non-linear statistical modeling to examine potential thresholds is on the rise but linear models still prevail in ecological literature, making it more difficult to define breakpoints or thresholds. Non-linear thresholds beyond which land use change will result in the degradation of ecosystems are rarely quantified. It is even more rare for researchers to take the additional step of forecasting the foreseeable expected changes to the landscape and assessing their effects. We also need an understanding of how the environment responds under different initial conditions, in order to maximize marginal gains (greatest response per increment of change) that may result from proposed changes to future land use and restoration.

For example, recovery of coastal salmon populations along the coast of California involves many small watersheds and upland tributaries, some of which have extensive land use and water demand by residents and agriculture that has led to degraded habitat; others are relatively undeveloped and support good salmonid spawning habitat. Restoration of the most disturbed watersheds may be too costly and difficult to expect any marginal gains. On the other hand, there is little opportunity for salmon recovery in relatively undisturbed watersheds. However, efforts in areas with moderate amounts of urban and agricultural development could result in more substantial marginal gains and ultimately lead to crossing a threshold required for salmon recovery – making

For managers and planners, there is a strong desire to know at what particular point the level of disturbance crosses a threshold -- leading the organizing processes of the system to change from one state to an alternative, potentially more degraded state.

It is hard to disagree that monitoring is essential for adaptive management, and we must view private land-conservation tools similarly and monitor their outcomes in order to better adapt our methods in the future.

these watersheds the most cost-effective places to begin restoration efforts.

While the state trajectories of certain ecological systems such as lakes have been extremely useful in increasing our understanding of ecosystem resilience (Carpenter et al. 1997 and 2001), many coupled human and natural systems remain unstudied, making it difficult to provide planners and managers with guidelines on how to manage for resilience. The impacts and thresholds associated with exurban development for woodlands and forestlands across the United States is a good example where almost nothing is known with respect to thresholds.

We recently completed a study on land use and its impacts on salmon spawning grounds in 87 watersheds throughout the Russian River in Sonoma County, California. Here the highest-quality spawning grounds are gravel beds, but fine sediment from erosion in the uplands may silt these gravel beds, making them unusable for salmon. We found that the urban and vineyard land uses had non-linear, negative relationships with salmon spawning substrate quality (Lohse et al. in prep), consistent with our previous work using linear models on lower resolution data (Opperman et al. 2005) and other studies (Wang et al. 2001, Pess et al. 2002, Morse et al. 2003).

Unlike previous studies, we were also able to examine the non-linear effects of exurban land use, and found that this land use category was a significant predictor of the distribution of fine sediments. Increases in the percent of total exurban development in a watershed significantly reduced the odds of observing high-quality habitat. Although urban development had the largest marginal effects, exurban development will affect a much larger land area. The land use change model that we developed for this research predicted that over the next decade, ten times as much land will become developed in exurban as in urban areas. Further, future urban development will tend to be clustered in areas that already have high levels of urban development, and thus already had little high-quality spawning habitat. Exurban development, however, is predicted to occur in watersheds that range from the least developed to the most developed, and will affect reaches that currently have small to moderate amounts of land use. Thus, exurban development will likely have a much greater overall impact than urban development on spawning conditions in Russian River basin streams over the next decade. Given the very low population densities of exurban development, the per-person effect on the environment of this type of development is large.

More studies using this approach are needed to examine the non-linear response of different types of land use change on measures of environmental condition, so we can better inform planners about the potential impacts of land use on multiple environmental benefits. These studies should also attempt to forecast how future development scenarios can influence the environment in order to provide decision-support systems. Unfortunately, the complexities and non-linear behavior inherent in ecological systems mean there is a great deal of uncertainty in predicting the extent and nature of changes in natural systems from human perturbations, which vary widely in their type and impact.

Policy outcomes and tradeoffs

It is hard to disagree that monitoring is essential for adaptive management, and we must view private land-conservation tools similarly and monitor their outcomes in order to better adapt our methods in the future. This is true for commonly employed incentive-based tools, such as conservation easements, as well as for regulatory tools such as zoning and urban growth limits. For example, little is known about the ecological outcomes of conservation easements at the local or landscape scale, despite the increasing acreage and public investment in this approach (Merenlender et al. 2004). It is even more difficult to determine how the regulatory tools change future development patterns. Sewer and water services may be the most important determinant of urban and suburban development; however this infrastructure does not constrain exurban development, which by definition is not dependent on such services (Newburn and Berck 2006). So policies that may curtail urban sprawl may not be the same as those needed for reducing exurban expansion trends. For example, urban growth boundaries are a recent popular tool for limiting sprawl (Quigley and Raphael 2004), but they can have the perverse effect of pushing development beyond the cities, and probably have little effect on exurban development. The complex trade-offs that are made when land use policies such as growth limits and zoning are enacted need to be examined further through an integrated modeling approach.

Current policy options are being adopted with little attention to the actual outcomes of these policies for curtailing the loss of open space. Transportation and urban economic models have explored lower land costs, and we know that inexpensive transportation costs can influence development distance from the central business district (Fujita 1999). But we still need spatially explicit models that integrate policy and economics with landscape ecology to explore how policy tools such as urban growth boundaries influence the pattern of development, including low density development; Newburn and Bercks' (2006) empirical model provides fertile ground for these ideas. Planning for development across urban and rural areas involves complicated landscapes and economies, which is why most policies are likely to have unintended consequences (Nechyba and Walsh 2004). It is critical that we work across disciplines, including land economics, landscape ecology, and land use planning, to see how policies have influenced development patterns and land conservation as well as other concerns, such as air pollution, associated with sprawl. We also need to examine the inherent trade-offs associated with various policy options so we can inform local decision-makers of these trade-offs and offer better tools for private land conservation. This is an important new direction for land use planning, however, a simple set of policy recommendations are unlikely to arise.

Take-home points

- Increasing our understanding of land use patterns and processes, particularly with respect to the drivers and consequences of exurban development, is critical in order to stave off what has become the largest growing source of habitat fragmentation on privately owned open space in the United States.
- Exploring the consequences of combining correlated and uncorrelated environmental benefits across real landscapes for prioritizing land acquisition will greatly improve our ability to help public and private organizations optimize their investments in land conservation.
- Quantifying the causal relationships between land use and environmental responses, using improved non-linear analysis methods to explore thresholds and their sensitivity to other environmental variables, is critical if we are going to advise planners how to avoid crossing these thresholds to maintain ecosystem process and function. Also, measuring the trajectory that degraded ecosystems take following restoration treatments or other alterations is essential to plan for ecosystem recovery.
- We must monitor outcomes from the existing land use planning and incentive-based conservation tools used to protect privately owned open space. Also, spatially explicit models should be developed that incorporate land use dynamics, economics, and landscape ecology to explore the tradeoffs inherent in policies designed to curtail urban sprawl and exurban expansion.

What can land use planners and regulators do that would help lead to the conservation and recovery of biodiversity?

There has been widespread recognition that having local governments be responsible for their own land use planning in a vacuum has been disastrous for regional development patterns, since policies adopted in one city or county affect neighboring jurisdictions. Coordinated regional planning is on the rise. However, in many places counties are dealing with sprawl because cities are not absorbing additional growth through increasing development density and providing attractive high-density development. Coordinated regional planning across multiple jurisdictions is essential to address the problem of exurban development that is operating at a larger scale than single local jurisdictions. One excellent study of the benefits and necessary elements for successful regional planning, "Regional planning in Michigan: Challenges and opportunities of intergovernmental cooperation" (Center for Local, State, and Urban policy 2005), reveals that most successful regional efforts get going to save on costs. And if competing goals and turf issues can be avoided, trusting relationships can be built and regional planning efforts sustained over

Coordinated regional planning across multiple jurisdictions is essential to address the problem of exurban development that is operating at a larger scale than single local jurisdictions.

time to improve cross-jurisdiction communication, increase information sharing, and reduce costs.

Another method for facilitating regional planning is the programmatic environmental impact report, which addresses environmental review for multiple pending and possible future projects within a particular region. This type of comprehensive review often results in a regional plan that allows development in designated areas to proceed without further environmental review. This is an incentive-based approach, because in the end developers save time and money by not having to do further environmental review as each individual project rolls out in the area covered by the programmatic review. Unfortunately, most governments and developers wait too long before they use this tool. This is because “business as usual” is not too costly or time-consuming until natural resources are taxed to the point of needing protection, which can then hold up development – as in the case of endangered species recovery. At that point, the options and costs for land protection are extremely limited.

For example, in the Laguna de Santa Rosa plain, where an endangered California Tiger Salamander population was preventing further development, a 2:1 mitigation ratio is now required as part of a conservation plan. With land costs as high as $300,000 an acre, this will result in roughly $30,000 being tacked on to the purchase price of each additional housing unit. We need to convince local governments that are not yet faced with these crises to levy fees early on that allow for conservation of land and associated natural resources while the options for retaining habitat connectivity at a larger scale remains, which in most cases is less expensive than when development has crossed a threshold that results in limited habitat and rare and endangered species. These plans often require complex ecological and economic analysis; therefore, a science panel, similar to those required by California’s Natural Communities Conservation Planning process, should be required for all regional plans and programmatic EIRs to address tradeoffs between development and the environment.

Local government institutions need to be better integrated to address both pull factors that foster higher-density development, through financial incentives for lower-income housing with amenities such as security, parks, and good schools; as well as the usual push factors used for conserving open spaces, through tools such as zoning or incentives like trading development rights or purchasing easements. All too often, conservation planning tools only provide push factors that limit development on farms and wildlands. Protecting land from development may prevent habitat conversion locally, but these restrictions on land supply may not be an effective way to shape future regional growth patterns. The regional demand for land remains despite land protections, and growth will shift to other unprotected locations.

Unfortunately the drivers that create demand for rural residential development do not go away, and therefore this type of development is pushed to other areas not currently protected. This is why open-space protection on private land must coordinate policies that both push development away from sensitive areas where environmental impact thresholds may be crossed, and pull development inside service boundaries – which, as discussed above, may require coordinated planning between cities and counties. Irwin et al. (2003) demonstrate that extending public sewer and water infrastructure may guide urban growth to designated target areas more effectively than placing easements on existing farmland, demonstrating that public infrastructure projects are necessary to redirect and concentrate regional development, and hence to serve conservation objectives.

It is important that we encourage local governments to invoke fees and taxes to pay for enacting these pull and push factors (Brueckner 2000), and again these efforts can work best if they are coordinated as a single policy initiative to generate widespread support. Special open-space and urban housing districts can be established to acquire land and facilitate desired development. Another method of funding these desired outcomes is to enact policy that allows mitigation of project impacts to be accomplished through fees paid to government agencies, such as open-space districts or resource agencies that have a land acquisition program. This will increase the chances that off-site mitigation efforts will be enacted through a coordinated conservation planning effort.

For example, in 2001 California passed legislation that facilitates off-site mitigation of habitat loss by offering an option to donate funds to the California Oak Woodlands Conservation Program. This program is focused on the purchase of conservation easements to protect California's privately owned oak woodlands. The California Wildlife Conservation Board is authorized to purchase oak woodland conservation easements and to provide grants for land improvements and restoration efforts. While the Program is coordinated at a statewide level, it provides opportunities to address oak woodland issues on a regional priority basis. This approach can be useful for conserving habitat types that are widespread, and hence more conservation benefit can be gained from off-site mitigation rather than traditional mitigation approaches such as moving and planting trees. However, these off-site mitigation solutions should always complement stringent requirements to minimize environmental degradation on the project site. Providing funds for regional land conservation from mitigation funds may not work well if the proposed development project affects habitats with extremely restricted distributions, since these habitats may not be able to withstand any further development or may require very local mitigation solutions.

One of the most common ways to prevent further subdivision of large privately owned land parcels without changing the zoning is through trading development rights, which involves the sale of development rights, usually from areas prezoned as "sending," and allows for more development than currently zoned for in designated "receiving" areas. Trading development rights programs have been in place for some time for agricultural land protection, as in New Jersey and Maryland. In these voluntary programs, landowners can sell "development credits" to developers in exchange for removing subdivision rights from their property title. Due to the voluntary nature of many of these programs, they often do not have clear restrictions on sending and receiving zones, but more commonly follow planning guidelines such as restrictions on slope (Johnston and Madison 1997). In many cases the credits allow for increased development density in certain areas, and sometimes can lead to a reduction of environmental standards for a particular project. In this way TDR credits serve as a type of mitigation for environmental impacts. This is the case in Lake Tahoe, California, where the building envelope can be enlarged beyond regulation size if another property's building coverage area in the same watershed is retired.

For conservation of natural resources, it is best if these programs carefully designate sending areas so as to maximize the environmental benefits. Receiving areas should ideally be within the service boundaries, already zoned at a relatively high density (e.g. 1-5 acres), and/or within unincorporated towns to substantially increase development densities and reduce economic, social, and environmental costs. Also, if it is important to protect the land adjacent to the sending zone, these areas should have some form of protection in perpetuity, either through the TDR program or another tool; otherwise these areas will be highly susceptible to growth after the receiving areas have been fully built out. However, the opportunity to sell and buy rights can increase the opportunity costs of both sending and receiving sites, and can accelerate growth and increase property values due to speculation on increased growth opportunities. These programs work best when they are well-planned and executed at a time when options for receiving zones are plentiful, rather than waiting until options for zoning are highly constrained.

The most important zoning objective for preventing habitat fragmentation on private lands and protecting biodiversity should be to discourage and remove areas zoned for medium-sized lots less than 100-200 acres and greater than 2 acres. As discussed above, this can be done through TDR programs. But perhaps more desirable would be for local government to set maximum lot sizes for development of 1-5 acres, and only use minimum parcel size for large agricultural and natural areas over 160 acres/parcel or more. This approach is intended to address habitat loss, degradation, and fragmentation associated with the low-density rural residential development described as exurbia above.

Leaving all the complexities of land use planning to local government is highly problematic, given that most local governments in the United States are under-funded and often cannot afford the necessary staffing levels and expertise required for the job. To

If applied scientists want to influence the local planning process, they must become involved in jointly developing programs that will ultimately be adopted and help planners and representative decision-makers.

improve habitat conservation through better land use planning, applied science needs to interface with planners to assess critically whether or not current policies to conserve open space and stave off sprawl actually produce the desired effect, as discussed in the research section above. This means professional planners need to see their work as adaptive by nature, and be willing to expend some resources on monitoring and evaluation despite the daily pressure they are under to address more pressing issues.

Take-home points

- City, county, and regional planning must be tightly coordinated in order to improve large-scale habitat conservation and contain sprawl.
- Regional plans that incorporate programmatic EIRs should be encouraged as early as possible, to reduce costs that increase dramatically when options for conserving critical habitat for endangered species are constrained by future build-out. The development of these should require a science panel during the planning phase similar to the NCCP process.
- It is critical that conservation and land use planners better integrate both incentives that push development away from priority natural areas, and those that pull development toward areas that are already developed and have service infrastructure.
- Fees and taxes should be levied to pay for open-space acquisition that will prevent habitat fragmentation and protect farmland, and to subsidize amenities that can be attractants for infill, such as parks, city landscaping, recreation centers, low-cost housing, better schools, and safe streets.
- Options for mitigation of habitat loss should include funding off-site land acquisition to maximize environmental benefits from the money spent on mitigating environmental impacts, and these funds should be managed by regional or statewide public agencies with public oversight and conservation plans in place.
- Programs designed to take advantage of trading development rights should be well-planned, including making sure that sending zones will result in protection of large continuous ownerships for habitat protection while receiving zones result in high-density development and not additional exurban development. Increased property values and rates of development should be expected in certain areas as a result of these programs.
- Removing and preventing rural residential parcel sizes from approximately 5-75 acres should be a very high planning priority, possibly by zoning for maximum lot sizes of approximately 2 acres for residential development rather than setting minimum densities for residential areas. Minimum parcel sizes should only be used for agricultural and rural lands that support environmental services and require large, less-fragmented landscapes.
- A more adaptive process that involves monitoring the impacts of local decision-making on resulting patterns of land use and conservation should be adopted by local planners. This approach requires outcomes research that quantifies the effectiveness of commonly applied land use and conservation policies intended to prevent sprawl and protect open space.

What practices would help convey science-based information to land use planners?

I regularly attempt to extend scientific information, research results, and decision support systems to planners and other people working in local and state government, as well as to board members responsible for decision-making. My insights on the process and how it may be improved are based on my own personal experience in northern California, rather than on extensive scholarly research. Also, I am forced to make some broad generalizations about planners for the sake of this essay that of course do not hold true for all planners in all settings. It has been my experience that scientists can not build a decision-support system or provide any other source of information and simply expect that those it would best serve will simply use it. If applied scientists want to influence the local planning process, they must become involved in jointly developing programs that will ultimately be adopted and help planners and representative decision-makers.

I have found that the best approach is to engage intended users of the information in the development of the project by having them invest financially, if at all possible, since that will make them very interested in the outcomes and motivated to use the resulting information. All too often, local governments pay private planning consultants who rarely provide real leadership by challenging government institutions and their staff to explore the most fruitful directions and solutions to the problem. There is a critical need for academics to become more involved in real-world planning in order for science to influence policy.

It is also my experience that planners work with a very local network of contacts from whom they seek information, which rarely goes beyond county staff resources and familiar consulting firms. This means that the best way to increase the role of science in the process is to increase the number of scientists involved in county government and the science literacy of planning and other staff working for local government. A good example is University County Cooperative Extension, where land-grant university academics work in county government to provide expertise on agricultural, human, and natural resources. These expert advisors are linked to research-based institutions while receiving support from local government, and are viewed as “in-house” by local government employees.

This institutional relationship, established with the land-grant colleges, is under-supported and under-utilized. County advisors or agents regularly present to supervisors and city council members, and maintain good relationships with state legislatures. Environmental scientists should take more advantage of University Cooperative Extension, which exists in almost all states and counties. This is especially true now, when many of the issues that even the most traditional production agricultural advisors face are environmental in nature. Other local government departments that are often interested in implementing science-based decision-making include those who are in charge of information technology (geographic information systems and data repository); special districts for open space, which often run semi-autonomously; and resource conservation districts, which often have their own, more focused planning staff.

Another important criterion that must be adhered to is to ensure that all science-based information is presented in context and clearly relevant to the problems that planners and other government staff are experiencing. Local government is under-staffed and under-supported, and these people do not have time to worry about issues that are not immediately pressing. This means that to serve them best, a two-way street of communication must exist so that applied research is directly informed by the issues that are most critical to planners. Academics, and even scientists working for state agencies and non-governmental organizations, can be far too removed from the world of local planning to take stock of what is really needed on the ground. Again, this is where having “in-house” academics in place can help identify emerging environmental issues where targeted research could help.

It would be nice to think that training local planners is an attractive approach; unfortunately I am often reminded that even leaving the office for a one-day workshop can be next to impossible given some planners’ work loads. However, we must try to augment planners’ information by finding support for them to attend training opportunities and lobbying for better support for the natural resource experts on whom they rely, such as University Cooperative Extension. Once again, any training or literature must be focused on their most pressing issues in order to justify the time required to participate or to read the material.

We must try to augment planners' information by finding support for them to attend training opportunities and lobbying for better support for the natural resource experts on whom they rely.

Another reason generic decision-support systems don’t work is that planners have an inherent distrust of models, and to convince them of their utility requires regular interactions on model development and the use of very high resolution data (e.g. parcel level). It is absolutely critical that the rules they follow and local data be integrated into any analysis and decision-support tools (Newburn et al. 2005, Merenlender et al. 2005). They do need help integrating local data into their decision-making process, but this requires large amounts of time on behalf of the investigator, and planners who have sufficient time to address conservation issues.

While scientists often use technology and the world-wide web to make science information available to the public, we need to do a much better job of marketing these sources of information and using the web to survey planners about pressing issues and how best to provide them with environmental information. Similar to the questions addressed in the first part of this essay, we need to evaluate which types of extension work best to increase the extent to which conservation science can influence land use planning, by studying what works and what does not. This requires outcomes research following all projects that are designed to improve conservation planning at the local level. For example, follow-up studies and surveys could determine to what extent decision-support tools, such as Vista developed by Nature Serve, and education materials provided to planners are actually used. This is fortunately being done by the Environmental Law Institute to determine the utility of their recent outreach materials for planners on conservation thresholds (Environmental Law Institute 2003).

Effective conservation planning needs to involve the public as well as planning professionals. Planners and local government decision-makers serve the public and are greatly influenced by what they perceive the public to be willing to accept. Thus, the public also needs education in scientific literacy and conservation of natural resources. This is often accomplished through a collaborative conservation process that is based on public participation. In an attempt to define a common language for this approach to decision-making and to share lessons learned from case studies, the Sonoran Institute published a very useful report titled "Beyond the Hundredth Meeting: A Field Guide to Collaborative Conservation on the West's Public Lands" (Cestero 1999). This investigation offers helpful guidelines for improving the success of public processes that are a necessary part of conservation planning.

Clearly there is no quick fix for informing planners about conservation science. Hopefully the following conclusions will add to our collective understanding of how we can improve the integration of conservation science into the planning process at the local level.

Take-home points

- Applied scientists must work with planners on developing decision-support tools to increase the chances that the information developed will be used.
- Planners, along with the county natural resource advisors on whom they rely, require more support to take advantage of training, which should be focused on emerging issues in order to attract participation.
- Planners and the public are often skeptical of models and their outputs, so high-resolution data should be used to improve model accuracy. In order to be used, models must be developed in close collaboration with planners and extended to the public to increase their acceptance.
- Websites and other sources of information require better marketing to planners, including soliciting their opinions to influence what information needs to be extended and how best to provide the information to them.
- Studies need to be conducted on the relative effectiveness of the various methods for improving the use of conservation science among land use planners.
- Collaborative conservation efforts that involve the public are critical for success.

Literature cited

Abbitt R.F., J.M. Scott and D.S. Wilcove. 2000. The geography of vulnerability: incorporating species geography and human development patterns into conservation planning. *Biological Conservation*. **96**:169-175.

Bennett, E. M., T. Reed-Andersen, J. N. Houser, J. R. Gariel, and S. R. Carpenter. 1999. A phosphorus budget for the Lake Mendota watershed. *Ecosystems*. 2(1):69-75.

Brown, D.G., K.M. Johnson, T.R. Loveland, and D.M. Theobald. 2005. Rural land-use trends in the conterminous United States, 1950–2000. *Ecological Applications*. 15(6):1851-1863.

Brown, D.L., G.V. Fuguitt, T.B. Heaton, and S. Waseem. 1997. Continuities in size of place preferences in the United States, 1972-1992. *Rural Sociology*. 62(4):408-428.

Brueckner, J.K. 2000. Urban sprawl: Diagnosis and remedies *International Regional Science Review*. 23(2):160-171.

Carpenter, S.R. and K.L. Cottingham. 1997. Resilience and restoration of lakes. *Conservation Ecology*. 1(1):2.

Carpenter, S.R., B. Walker, J. M. Andries, and N. Abel. 2001. From metaphor to measurement: Resilience of what to what? *Ecosystems*. 4:765-781.

Center for Local, State, and Urban Policy, University of Michigan 2005. Regional planning in Michigan: Challenges and opportunities of intergovernmental cooperation. http://closup.umich.edu/research/reports/pr-3-reg-gov.pdf (Accessed February 27, 2007.)

Cestero, B. 1999. Beyond the hundredth meeting: A field guide to collaborative conservation on the west's public lands. Page 81. Tucson, Arizona: Sonoran Institute.

Costello, C and S. Polasky. 2004. Dynamic reserve site selection. *Resource and Energy Economics*. 26:157–174.

Crump, J.R. 2003. Finding a place in the country: Exurban and suburban development in Sonoma County, California. *Environment and Behavior*. 35(2):187-202.

Donahue, I., M.L. McGarrigle, and P. Mills. 2006. Linking catchment characteristics and water chemistry with the ecological status of Irish rivers. *Water Research*. 40:91-98.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C.S. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology and Evolution and Systematics*. 35:557-581.

Fujita, M. 1999. *Urban Economic Theory: Land Use and City Size*. Cambridge, UK: Cambridge University Press.

Hansen, A.J., R.L. Knight, J.M. Marzluff, S. Powell, K. Brown, P.H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. *Ecological Applications*. 15(6):1893-1905.

Harte, J. 2001. Land use, biodiversity, and ecosystem integrity: The challenge of preserving earths' life support system. *Ecology Law Quarterly*. 27: 929-965.

Heimlich, R.E., and W.D. Anderson. 2001. "Development at the urban fringe and beyond: Impacts on agriculture and rural land." Agricultural Economic Report No. 803. Washington, D.C.: U. S. Department of Agriculture, Economic Research Service.

Hilty, J. A., C. Brooks, E. Heaton, and A. M. Merenlender. 2006a. Forecasting the effect of land-use change on native and non-native mammalian predator distributions. *Biodiversity and Conservation.* 15(9): 2853-2871.

Hilty, J.A., W.Z. Lidicker, and A. M. Merenlender. 2006b. *Corridor Ecology: The science and Practice of Connectivity for Biodiversity Conservation*. Washington, DC: Island Press.

Holling, C.S., and L.H. Gunderson. 2002. Resilience and adaptive cycles. In L.H. Gunderson and C.S. Holling, eds. *Panarchy: Understanding Transformations in Human and Natural Systems*, pp. 25-63 Washington, DC.: Island Press.

Huggett, A.J. 2005. The concept and utility of ecological thresholds in biodiversity conservation. *Biological Conservation*. 124:301–310.

Irwin, E.G., K.P. Bell, J. Geoghegan, 2003. Modeling and managing urban growth at the rural–urban fringe: a parcel-level model of residential land use change. *Agricultural and Resource Economics Review* 32, 83– 102.

Johnston, R.A. and M.E. Madison. 1997. From landmarks to landscapes. *Journal of the American Planning Association*. 63(3):365-379.

Kareiva, P., S. Andelman, D. Doak, et al. (14 additional authors). 1999. Using science in habitat conservation plans. Report for National Center for Ecological Analysis and Synthesis and American Institute of Biological Sciences, Washington, DC. http://www.aibs.org/bookstore/resources/hcp-1999-01-14.pdf (Accessed February 27, 2007.)

Kennedy, C., J. Wilkinson, and J. Balch. 2003. *Conservation Thresholds for Land Use Planners*. Washington D.C.: Environmental Law Institute.

Lohse, K.A., D. Newburn, J. Opperman, and A.M. Merenlender. *In prep*. Mapping uncharted waters: Forecasting the relative impacts of recent and future land use on fine sediment in anadromous fish habitat.

Manley, P.N., D.D. Murphy, L.A. Campbell, K.E. Heckmann, S. Merideth, S.A. Parks, M.P. Sanford, and M.D. Schlesinger. 2006. Biotic diversity interfaces with urbanization in the Lake Tahoe Basin. *California Agriculture*. April-June 59-64.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. *Nature*. 405:243-253.

McCaull, J. 1994. The natural community conservation planning program and the coastal sage scrub ecosystem of Southern California. In R. E. Grumbine (ed.), *Environmental Policy and Biodiversity*. Island Press, Washington, DC.

Meir, E., S. Andelman, and H.P. Possingham. 2004. Does conservation planning matter in a dynamic and uncertain world? *Ecology Letters*. 7:615-622.

Merenlender, A.M., C. Brooks, D. Shabazian, S. Gao, and R. Johnston. 2005. Forecasting exurban development to evaluate the influence of land-use policies on wildland and farmland conservation. *Journal of Conservation Planning*. 1(1):64-88.

Merenlender, A. M., K.L. Heise, and C. Brooks. 1998. Effects of subdividing private property on biodiversity in California's north coast oak woodlands. *Transactions of the Wildlife Society*. 34:9-20.

Merenlender, A.M., L. Huntsinger, G. Guthey, and S.K. Fairfax. 2004. Land trusts and conservation easements: Who is conserving what for whom? *Conservation Biology*. 18(1):65-75.

Morse, C.C., A.D. Huryn and C. Cronan. 2003. Impervious surface area as a predictor of the effects of urbanization on stream insect communities in Maine, U.S.A. *Environmental Monitoring and Assessment*. 89:95-127.

Muradian, R. 2001. Ecological thresholds: A survey. *Ecological Economics*. 38:7-24.

Nechyba, T.J., and R.P. Walsh. 2004. Urban sprawl. *Journal of Economic Perspectives*. 18(4):177-200.

Newburn, D.A. and P. Berck 2006. Modeling suburban and rural-residential development beyond the urban fringe. *Land Economics*. 82 (4):481–499.

Newburn, D., P. Berck, and A.M. Merenlender. 2006. Habitat and open space at risk of land-use conversion: Targeting strategies for land conservation. *American Journal of Agricultural Economics*. 88(1):28-42.

Newburn, D., S. Reed, P. Berck, and A.M. Merenlender. 2005. Economics and land-use change in prioritizing private land conservation. *Conservation Biology*. 19(5):1411-1420.

Nillon, C.H., C.N. Long, and W.C. Zippererb. 1995. Effects of wildland development on forest bird communities. *Landscape and Urban Planning*. 32(8) l-92.

Odell, E.A., D.M. Theobald, and R.L. Knight. 2003. Incorporating ecology into land use planning: The songbirds' case for clustered development. *American Planning Association Journal*. 69(1):72-81.

Odell E.A. and R.L. Knight. 2001. Songbird and medium-sized mammal communities associated with exurban development in Pitkin County, Colorado. *Conservation Biology*. 15:1143-1150.

Opperman, J. J, K. Lohse, K., C. Brooks, C., N. M. Kelly, and A. M. Merenlender. 2005. Influence of land use on fine sediment in salmonid spawning gravels within the Russian River basin, California. *Canadian Journal of Fisheries and Aquatic Science*. 62:2740-2751.

Parrish J.D., D.P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. *BioScience*. 53:851-860.

Parsons, H., K. French, and R.E. Major. 2003. The influence of remnant bushland on the composition of suburban bird assemblages in Australia. *Landscape and urban planning*. 66:43-56.

Pess, G.R., D.R. Montgomery, R.E. Bilby, A.E. Steel, B.E. Feist, and H.M. Greenberg. 2002. Landscape characteristics, land use, and coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., USA. *Canadian Journal of Fisheries and Aquatic Sciences*. 59:613-623.

Phillips, J.D. 2006. Evolutionary geomorphology: Thresholds and nonlinearity in landform response to environmental change. *Hydrology and Earth System Sciences Discussions* 3:365–394.

Quigley, J.M. and S. Raphael. 2004. Is housing unaffordable? Why isn't it more affordable? *Journal of Economic Perspectives.* 18(1):191–214.

Radeloff, V.C., R.B. Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The wildland–urban interface in the United States. *Ecological Applications*. 15(3):799–805.

Reynaud, P.A. and J. Thioulouse. 2000. Identification of birds as biological markers along a neotropical urban-rural gradient (Cayenne, French Guiana), using co-inertia analysis. *Journal of Environmental Management*. 59:121-140.

Scheffer, M., S. R. Carpenter, J.A. Foley, C. Folke and B. Walker. 2001. Catastrophic shifts in ecosystems. *Nature*. 413:591-696.

Stoms, D.M., P.J. Comer, P.J. Crist, and D.H. Grossman. 2005. Choosing surrogates for biodiversity conservation in complex planning environments. *Journal of Conservation Planning*. 1:44-63.

Sutton, P.C., T. J. Cova, and C. Elvidge. 2006. Mapping exurbia in the conterminous United States using nighttime satellite imagery. *Geocarto International*. 21(2):64-88.

Theobald, D. M. 2001. Land-use dynamics beyond the American urban fringes. *Geographical Review*. 91: 544-564.

Trust for Public Land. 2005. LandVote 2005. Washington, DC: The Trust for Public Land and Land Trust Alliance.

Walker, P.A. and L.P. Fortmann. 2003. Whose landscape? A political ecology of the "exurban" Sierra. *Cultural Geographies*. 10(4): 469-491.

Wang, L., J. Lyons, and P. Kanehl. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management*. 28(2): 255 – 266.

Williams, P.H. and M.B. Araujo. 2002. Apples, oranges, and probabilities: Integrating multiple factors into biodiversity conservation with consistency. *Environmental Modeling and Assessment*. 7:139-151.

Wilson, K.A., M.F. McBride, M. Bode, and H.P. Possingham. 2006. Prioritizing global conservation efforts. *Nature*. 440:337-340.

With K.A. 2002. The landscape ecology of invasive spread. *Conservation Biology*. 16:1192-1203.

Zbinden, S. and D.R. Lee. 2005. Paying for environmental services: An analysis of participation in Costa Rica's PSA program. *World Development*. 33(2):255–272.

Views of a Conservation Biologist

Dan L. Perlman, Ph.D., Brandeis University

Introduction

Many aspects of modern human society draw heavily on the basic sciences. Good engineering depends on a solid understanding of physics, just as materials science and public health depend on chemistry and basic biomedical sciences respectively. Land use planning calls on conservation biology for guidance, and conservation biology is based in turn on the science of ecology; yet these applications of science are very different from the previous examples. It is worth examining how the relationships among land use planning, conservation biology, and ecology differ from the relationships between the previously mentioned applied and basic sciences.

First, there is the matter of goals. Highway bridges, automobiles, cookware, and pajamas must meet standards for safety, longevity, and efficiency that are set by governments and the marketplace. The goals of public health are more difficult to pin down, perhaps in part because there is no marketplace to set standards; instead, we depend on international bodies, governments, and non-governmental agencies to set targets for lowered death or disease rates. Setting conservation goals is even more difficult, since they include targets such as: increased ecosystem health (if human health appears difficult to measure, ecosystem health is far worse); increased populations and augmented genetic diversity of endangered species; decreased populations of invasive species; improved management of disturbances (such as fire) throughout a region; increased public awareness and support; and improved public access to protected lands. In short, designing a highway bridge is in some ways far easier than designing a conservation plan, because there the goals can be relatively easily defined. Conservation planners face an additional problem: the ecosystems and human communities where they work frequently shift in fundamental ways, such that the conservation goals must shift as well.

Second, the underlying sciences of physics, chemistry, and biomedical studies differ greatly from ecology and conservation biology. Physics, chemistry, cell biology, and genetics all focus, by definition, on discovering universal understandings and general laws. In contrast, while ecologists and conservation biologists would like to uncover general laws, their sciences are among the most historical of all, since past ecological conditions place great constraints on the present and on future ecological possibilities. In fact, it is frequently stated that the First Law of Ecology is: "It Depends."

To highlight the difference among sciences, recall that in 1989, scientists at the University of Utah announced that they had achieved "cold fusion" – the release of large amounts of energy by fusing atoms at a relatively low temperature. Within months, labs around the world were attempting to duplicate these experiments, but none were able to replicate the findings. This pattern of attempting replication of results occurs in other laboratory sciences as well, when potentially important findings are reported. In ecology and conservation biology, however, stunning new reports do not lead to flurries of replication—in large part, because it is simply impossible to truly replicate a conservation biology or ecology study (see Figure 1).

For example, consider a recent study demonstrating that conservation corridors can be useful in linking subpopulations of Florida black bears *(Ursus americanus floridanus)* in the Osceola and Ocala National Forests (Dixon et al. 2006). This result, however, does not necessarily mean that a similar corridor between the Tensas and Atchafalaya river basins in Louisiana will help the threatened Louisiana black bear *(Ursus americanus luteolus)*—even though it is a closely related subspecies in a nearby region. If cold fusion works in Utah, it will work in New York. But if conservation corridors work for black bears in northern and central Florida, they may or may not be effective for black bears in Louisiana, or for Florida panthers in southern Florida, or for wolves in Montana. By definition, historical differences *always* exist between different populations, subspecies, and species—and the landscapes that they inhabit differ as well. If one lab claims that cold fusion works while twenty labs using the same procedures say that it does not work, we can be confident that we have discovered a universal truth about the functioning of the universe. But when one conservation biology study claims that a conservation corridor worked while twenty others disagree, all we can say is that historical conditions may have allowed the one to work.

There are surprisingly few universal truths in ecology and conservation biology.

FIGURE 1. Ecological systems are ever-changing, often in ways that appear random over the short term. These four photographs were all taken on May 15 of consecutive years (2000-2003) - but note the striking variation in plant growth among the years.

There are surprisingly few universal truths in ecology and conservation biology. While engineers and materials scientists can turn to physics and chemistry for clear-cut universals, conservation biologists cannot lean on ecology in the same way. As a result, land use professionals looking for scientific input from conservation biologists and ecologists must recognize that they will get guidelines rather than clearly defined rules. Conservation biologists, too, must recognize the limits of what they can offer: while they have accumulated vast amounts of highly relevant information for land use planners, that information unfortunately cannot be distilled into easily and widely applicable rules.

In this essay, I first discuss several ways in which land use planners and regulators can make use of the findings of conservation biology to best improve the health of the land, both for the sake of native species and for humans. Then, I describe several key areas of conservation biology research that would be especially useful for improving the effectiveness of conservation efforts on the ground. Finally, I consider ways that conservation biologists and land use professionals can work more closely together.

What are the major gaps in the conservation biology research agenda that need to be filled to improve land use and conservation planning?

Improving priority-setting strategies.

Conservation biologists all agree that there is too little money and too few human resources to address all of the world's conservation problems. As the first sentence of a recent article in *Nature* states, "One of the most pressing issues facing the global conservation community is how to distribute limited resources between regions identified as priorities for biodiversity conservation." (Wilson et al. 2006) It is imperative that we set conservation priorities as effectively as possible, to avoid spending precious resources on less important problems. That said, several issues arise in attempting to set conservation priorities, because academic conservation biologists tend toward the following attitudes, as illustrated by the quotes from Wilson et al. (2006):

- *Viewing the setting of priorities as a technical problem to be addressed with scientific and technical solutions.* For example, "stochastic dynamic programming is used to find the optimal schedule of resource allocation for small problems but is intractable for large problems owing to the 'curse of dimensionality.' We identify two easy-to-use and easy-to-interpret heuristics that closely approximate the optimal solution" (p. 337). My response: Conservation biology problems are not so easily defined that they have "optimal solutions"; they are very complex, and there is no single technical solution to any real-world conservation problem.
- *Assuming that a single set of goals is shared by all conservation practitioners (biologists and others).* "Our objective is to maximize the number of endemic species remaining across all regions when habitat conversion ceases because there is no unreserved or unconverted land…" (p. 339). My response: While protecting endemic species is certainly a very important objective, many other conservation objectives exist and must be included in setting priorities. For example, protection of widespread but rare species, or species that are culturally important, may be highly valued, even if the species are not endemic.
- *Assuming that conservation biologists are in charge of setting conservation priorities.* "Species richness, or endemic species richness, is typically used to estimate the biodiversity value of a region" (p. 337). My response: The number of species (or of endemic species) is certainly used as a surrogate for biodiversity in many papers written by academic conservation biologists, in part because counting species is at least semi-feasible. But many other stakeholder groups have opinions about what kind of biodiversity is valuable in a region, and their voices need to be heard. Species richness is by no means the single best measure of conservation value.

As my colleague Glenn Adelson and I have argued previously, the setting of conservation priorities is a multi-faceted interaction among many different stakeholder groups—only one of which is the conservation biologists (Perlman and Adelson 1997). While we are strongly in favor of protecting as many of the world's species as possible, and especially endemics, we believe that a wide variety of human values need to be brought to bear in selecting conservation targets, and that conservation biologists are not the sole arbiters of which targets to select. Given that resources are limited, an all-out effort to protect every one of the world's species, and a focus just on species, will mean that many worthy conservation efforts will not get much attention. On the other hand, some hands-on conservation groups do take a multi-faceted view of their conservation mission, focusing beyond individual species. For example, "The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive" (ww.nature.org/aboutus/).

A wide variety of human values need to be brought to bear in selecting conservation targets, and that conservation biologists are not the sole arbiters of which targets to select.

Much of the conservation biology priority-setting literature has focused on finding the most efficient methods of getting complete coverage for a list of entities belonging to a single class—either all the species or all the different ecosystem types in a region (Pressey et al. 1993). In a different vein, however, Seth Guikema and Mark Milke have proposed using tools from the field of decision analysis to set priorities in multi-dimensional conservation problems (Guikema and Milke 1999). Unfortunately, their paper has not been widely noticed in the conservation biology world; according to Web of Science, the paper has only been cited five times as of June 2006 (and two of those citations are in other papers by the two authors of the original paper).

I am convinced that aiming for optimal solutions using extensive but very narrowly focused datasets (e.g., focusing only on the presence/absence of species) is not the most productive avenue we have for setting priorities among many potentially deserving conservation projects. I believe that the time is ripe to develop a wider range of priority-setting methods than conservation biologists have used to date.

Understanding the needs of native organisms and the functioning of native ecosystems, especially on small scales.

In most western states, Alaska, and Canada, conservation work is being envisioned and performed on grand scales. In the Yellowstone-to-Yukon (Y2Y) project, for example, conservationists envision creating corridors ten, or even twenty, miles wide in order to link existing reserves. To ensure that these proposed corridors fill the needs of the species being targeted, basic ecological studies continue to be performed on the dispersal patterns and habitat needs of large carnivores such as grizzly bears *(Ursus arctos horribilis)*, wolves *(Canis lupus)*, and wolverines *(Gulo gulo)*. At these geographic scales, however, it is clear that if we effectively protect habitats for "umbrella species" such as these, many other species will also receive effective protection of their habitats.

In the East, however, and in more heavily populated areas of the West, conservation must be performed in relatively small regions at small scales. In Connecticut, forty acres might contain an entire subdevelopment, instead of a single home, as might occur in Wyoming. At these small scales, planners do not have the luxury of assuming that the needs of hundreds of species will automatically be taken care of by planning for the needs of one or two species of large-bodied, wide-ranging carnivores. That said, careful understanding of the distribution and ecological needs of small-bodied plants and animals can lead to important protections, even if just a few dozen acres are conserved.

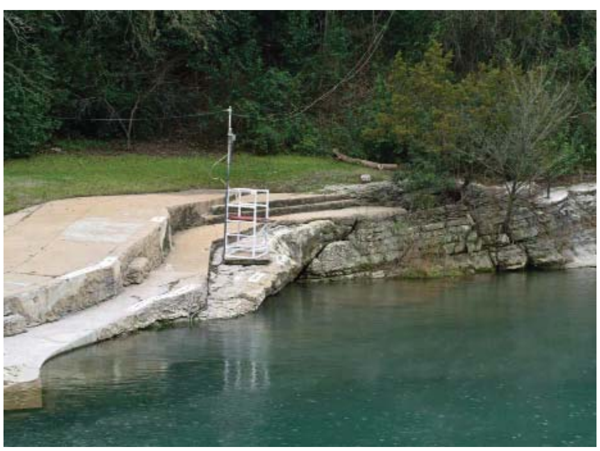

FIGURE 2. Barton Springs Pool in Austin, Texas. Nearly all of the world's population of the Barton Springs Salamander (Eurycea sosorum) lives in this public swimming pool; the others live in within sight of the pool in tiny springs.

The Barton Springs Salamander *(Eurycea sosorum)* is one of the most extreme examples of a vertebrate with a limited range (U.S. Fish and Wildlife Service 2005). This species is only known from a complex of springs found in Zilker Park in Austin, Texas, in or beside a natural public swimming pool. According to a map in the recovery plan for the salamander, these four springs are located in an area approximately 500 yards by 40 yards in extent (about four acres). Given that the fate of an entire species rests on the management of a heavily used municipal swimming pool, conservation biologists must learn all they can about the ecology of this (and other) species, and must communicate this knowledge to relevant government authorities (Figure 2).

Calibrating our research to focus on what is important; the conservation corridor issue.

Performing conservation biology research is fundamentally different from performing most other types of scientific research, including basic ecological research. As I described earlier, it is hard to come up with universal scientific truths in conservation biology. The problem is compounded by the fact that so many of the biodiversity elements on which we focus are in very delicate situations. When there are just a

couple of dozen California condors *(Gymnogyps californianus)* or whooping cranes *(Grus americana)* left in the world, it is extremely difficult to perform rigorous studies on their breeding biology—especially if those studies carry a risk of decreasing the reproductive output of even a single mated pair. Luckily, there were other, more common cranes and condors in the world that conservation biologists could study in attempt to learn more about increasing the population of these endangered species. But if there are key aspects of the species' biology that must be studied, such as their migration or dispersal behavior, there is no substitute for studying actual whooping cranes and California Condors. Similarly, if one is interested in the effects of fragmentation on the species and ecosystem functioning of old-growth redwood forests, there really is no substitute for studying these specific ecosystems.

An ecologist interested in the annual movement patterns of salamanders could choose to study any of the 44 species of lungless salamanders in the genus *Plethodon* (http://www.natureserve.org/explorer/servlet/NatureServe?loadTemplate=tabular_report.wmt&paging=home&save=all&sourceTemplate=reviewMiddle.wmt). But the conservation biologist interested in protecting federally listed *Plethodon* species would focus on just two of these: the Cheat Mountain salamander *(P. nettingi)* and the Shenandoah salamander *(P. shenandoah)*, which are listed as "threatened" and "endangered" respectively. It is certainly possible that a closely related (but not endangered) species from the same region, living in similar habitats, could give some useful comparison information on the salamanders' behavior, but if we are considering where to site a road near a known population of Cheat Mountain salamanders, we really need to know the movement patterns of this species.

This problem of needing to focus on specifics rather than generally applicable rules becomes especially acute in the case of conservation corridors. Conservation biologists agree that, before humans had major impact on landscapes, the natural world had more "connectivity"; organisms could move fairly freely from one location to another. As humans have divided up the landscape, we have decreased connectivity by destroying habitats and creating roads, making movement significantly more difficult and dangerous for native species. The way to restore connectivity, according to many conservationists and conservation groups is to create corridors. Unfortunately, an effective corridor for one species, say the Gray Catbird *(Dumetella carolinensis)*, may be a deathtrap for another, such as the endangered Key Largo Cotton Mouse *(Peromyscus gossypinus allapaticola)* when it exposes them to the depredations of domestic pets. Once again, it is the particulars of the ecology of each species that makes the difference.

Like all conservation biologists, I believe strongly that protecting large areas of quality habitat is the gold standard of conservation practice. I also believe that a truly "connected" landscape will be better than a fragmented landscape of disjointed habitats. That said, while maintaining high-quality corridors is essential, there is no one-size-fits-all corridor. Unfortunately, I do not see any way around specifying which organisms are the focus of a specific corridor, and then trying to accumulate the best research possible on the costs and benefits of the type of corridor being proposed for that specific organism. As conservation biologist Andy Dobson and fourteen co-authors wrote, "the first step in the analysis of corridor capability [should be] the selection of target species…. the idea of a generic landscape corridor — connectivity for the sake of connectivity — is more aesthetic than scientific and will generally be dismissed in the hard light of scientific review" (Dobson et al. 1999).

What can land use planners and regulators do that would help lead to the conservation and recovery of biodiversity?

Think of the landscape context; plan beyond the edges of the planning site or region.

Very early in their careers, conservation biologists and ecologists learn that the boundaries of ecosystems are quite flexible and permeable. Even if one has a clearly demarcated study site like a pond, outside influences such as weather, disturbances (e.g., fire and flood), and immigrating organisms may drastically change events within the site (Perlman and Milder 2005). Speaking from a conservation biologist's perspective, I would suggest that land use planners similarly adopt the habit of looking well beyond the boundaries of their official region of concern.

Given land use planners' focus on human health and safety, it is of course critical to consider ecological events that could impinge on the residents of a given area. But the converse is true as well: what happens within a given planning area can have major ecological effects that spill well beyond the boundaries of the site or region. In other words, what happens in Las Vegas does *not* stay in Las Vegas: local ecological events spill out to affect the ecology of the surrounding Clark County landscape, and extend far downstream along the Colorado River.

It is also critical to understand the context in which a specific conservation project sits. Imagine a fifty-acre farm property that comes up for sale in your region. The site includes a little forest and some wetlands: should the property be purchased or not? This question can only be answered by understanding the context. The parcel would be valued quite differently if (1) it were one of a few ordinary farms in a forested landscape, or (2) the forest is part of a critical conservation corridor, or (3) if the wetlands are an especially vulnerable and important part of a complex that provides water for humans (see Figure 3).

When humans insert themselves into a landscape, they affect a number of processes—all of which

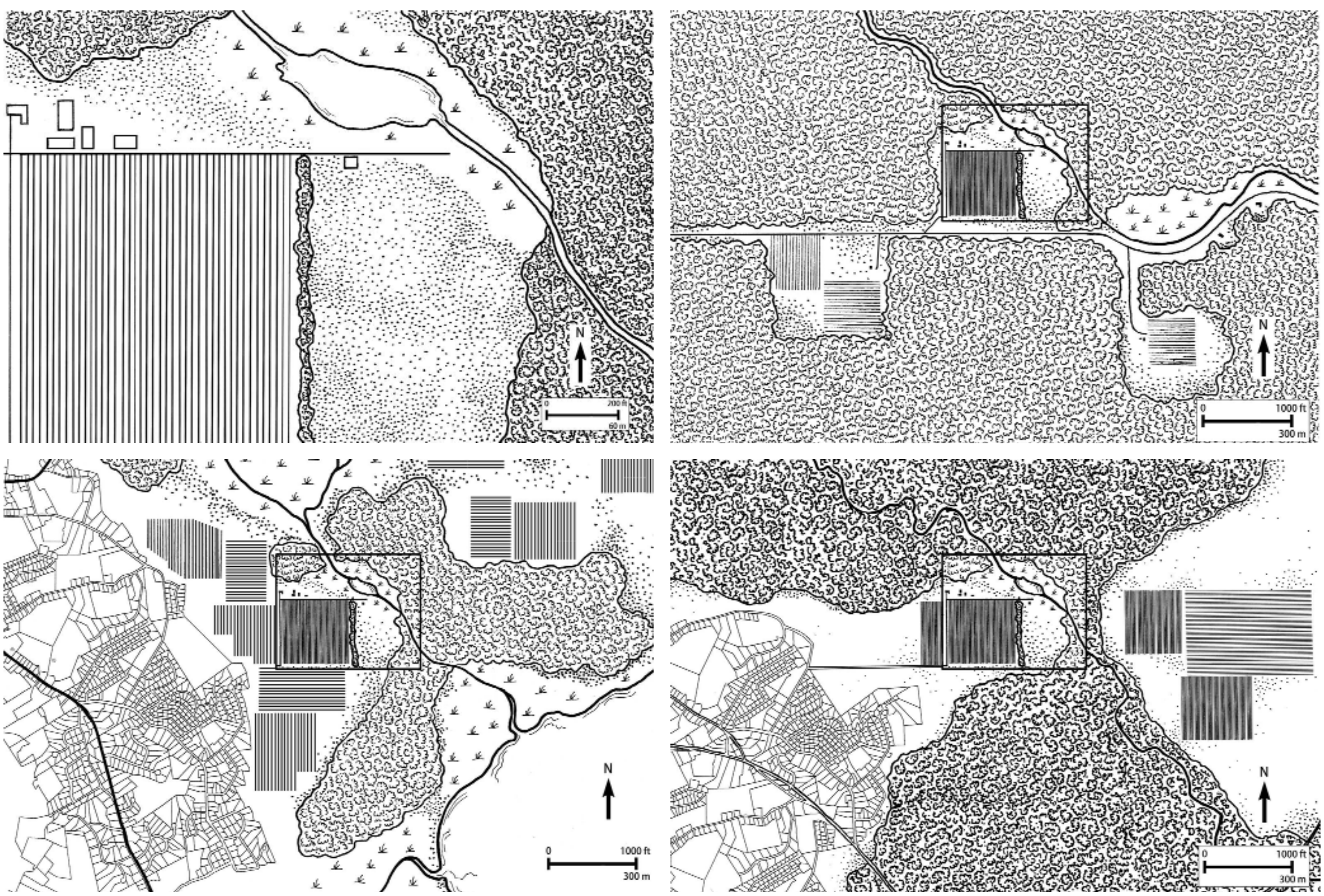

FIGURE 3(a - d). The conservation value of a given parcel depends heavily on its context. Figure 3a shows a hypothetical fifty-acre farm, that includes some a little forest and wetlands in addition to pasture and croplands. Figures 3b - 3d show this same farm in different contexts, to demonstrate that the site would have different types of conservation value depending on where it is located (images from Practical Ecology for Planners, Developers, and Citizens, used with permission from Island Press).

change the ecology of the larger region. In general, it is useful for planners to think about *flows* across the landscape. Water is an obvious example; when we create large amounts of impermeable surface such as pavement and rooftops, we change the hydrology of a region, especially the recharging of groundwater. Humans also change natural disturbance regimes, altering the natural patterns of fire and flooding (both of which can be seen as flowing across landscapes).

As has become apparent in the aftermath of Hurricane Katrina, dams on the Mississippi and Missouri Rivers have greatly decreased the accumulation of sediment in the Mississippi Delta, leading to a lowering of New Orleans and the surrounding area, which made the region more vulnerable to the effects of the hurricane. In addition, levees that straighten and speed the flow of the rivers – and that prevent flooding in one region – may have significant effects downstream, often leading to even worse flooding there. Regional planners in the upper Midwest may not regularly consider the needs of Louisiana residents, nor would Louisiana planners typically think about planning actions occurring in the upper Midwest; but actions upstream can have tremendous impacts on the people and native ecosystems downstream.

Understand the geographic scales used by specific organisms.

As a corollary of planning beyond the edges of a human-designated site or region, it is critical to know how organisms use the landscape. Consider a small pond, a vernal pool in New England, which might be home to the eggs and larvae of blue-spotted salamanders *(Ambystoma laterale)*, a "species of special concern" in Massachusetts and New York. We now know that many invertebrate and amphibian species make use of vernal pools for breeding, and many of these are rare enough to be listed by their respective states. This basic ecological understanding has been written into laws and regulations across the United States, so that these temporary small ponds are protected in many jurisdictions. In Massachusetts, where I live, vernal pools that have been certified by the state are protected under the Massachusetts Wetlands Protection Act as well as several other state and federal laws (Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, "Guidelines for the Certification of Vernal Pool Habitat").

That said, we also know that many of the organisms breeding in vernal pools are not full-time residents, as they migrate away from the water for much or most of the year. In Massachusetts, vernal pools receive up to a 100-foot buffer around the pool's margin if there is wetland vegetation in the area, and this would certainly seem to be sufficient for the few-inch-long blue-spotted salamander. However, a recent study determined that these salamanders move quite a bit farther: conservation biologist Jon Regosin and his colleagues found that more than half of the salamanders in their study traveled more than 100 meters (over 300 feet) from the breeding pond (Regosin et al. 2005).

Consider this situation, then, in a typical development. If there were a vernal pool 100 feet in diameter, a required 100-foot buffer around the edge of the pool would mean setting aside 1.4 acres of land to remain undeveloped. Establishing a 300-foot buffer—recalling that over half of the blue-spotted salamanders actually moved more than this distance each year—would require setting aside over 8 acres of land; and a 400-foot buffer would require more than 14 acres. The bottom line is that the 100-foot buffer, which is not even required by law in all cases, may be woefully inadequate—and once roads, homes, and driveways are spread around this area, there will be no opportunity to create a more appropriate buffer. Thus, we must understand the ecology of the organisms we hope to protect.

Make nature easily available in order to build long-term conservation constituencies.

Having large portions of the public be strongly supportive of conservation is critical for the long-term health of ecosystems and native species, so we need to continue to build an extensive and powerful conservation constituency. Clearly, the major conservation groups have this goal in mind, as they continually reach out to the public to raise awareness (and funds). I am a strong supporter of the efforts of these groups, having worked with staff and board members of The Nature Conservancy (TNC), World Wildlife

I think the only way to build long-term support for conservation is through long-term local connections to some piece of nature.

Fund-US (WWF-US), and Conservation International (CI). That said, I feel that these groups (and others) are missing a key long-term piece of the conservation puzzle with their tight focus on saving critically imperiled biodiversity regions around the world: "The Last Great Places" (TNC); "The Global 200" (WWF-US); "Biodiversity Hotspots" (CI).

The national and international conservation organizations are so focused on biodiversity conservation in high-profile/high-reward sites that they do not spend a great deal of effort on small sites and local education initiatives. I believe it is critical that each child and adult have access to some tract of "nature" nearby, even if it is tiny. Unless people form direct and personal connections to nature, it will be difficult to enlist their aid in conservation efforts around the world. I think the only way to build long-term support for conservation is through long-term local connections to some piece of nature; if people cannot connect with and appreciate their local nature areas, I do not think they will be committed supporters of distant areas. I clearly remember hearing Madhav Gadgil, India's leading ecologist and conservation biologist, state at a nation-wide conservation conference in India that every child in his country should be able to experience a little wilderness right near his or her home village (Gadgil 1998). This is what I would like for our nation, as well.

In order to make this a reality, I think we need to understand "park-sheds," the area over which people gravitate toward a given natural reserve area. We need to assemble a better understanding of how people get to the parks and reserves they visit, how often and how far they travel, what they do in the parks and how they affect the sites. I have not uncovered any significant research in this area as pertains to local neighborhood parks, although there is literature on the use of national parks and similar large reserves. Knowing how people use parks will help us know where to create them and what to include. Then, knowing the needs of human visitors, we can move on from there to consider the needs of native organisms.

If we are able to offer engaging nature experiences—locally—for a large portion of the population, there is a good chance of building a long-term nature conservation constituency. Even if these parks are small, isolated, and over-run by invasive non-native plants, they can serve a critical educational role. Creating and preserving small neighborhood parks is the responsibility of local and regional planners; without the specific efforts of planning professionals, parks full of nature will frequently be replaced by playing fields and housing. The future of the conservation-minded public gets played out in neighborhoods across the country each year, as local land use decisions create or destroy local parks.

Avoid exacerbating exotic species problems.

As part of appreciating nature, people typically enjoy being surrounded by attractive landscaping, especially flowering plants. Unfortunately, it turns out that quite a large number of non-native plants grow well in gardens *and* in native ecosystems, where they have few predators and parasites to keep their populations in check. In some cases, these species can become invasive, overwhelming native species and even taking over entire habitats; some notorious examples include purple loosestrife *(Lythrum salicaria)*, Norway maple *(Acer platanoides)*, and kudzu *(Pueraria montana)*.

All too often, it takes a long time for the information that a plant (or animal) species is invasive to get from the scientific community to the landscaping community and general population. Planners could play an especially important role by keeping track of invasives and working with designers and landscape architects to stop importing and using these ecologically dangerous species.

Planners can also help combat invasive species by avoiding habitat fragmentation wherever possible. Invasives typically enter native habitats from the edges or from trails, so planners can help protect native habitats in two ways: (1) reduce the amount of edge that the nature park possesses (that is, make parks plump rather than elongated) and (2) create fewer dissecting paths so that there is a larger, untouched interior patch of habitat.

What practices would help convey science-based information to land use planners?

Coordinate and expand current clearinghouses of relevant conservation biology information for planners.

Many government and non-governmental organizations maintain extensive guidelines for the conservation of certain species and habitat types. While a tremendous amount of excellent information exists, no single resource I know of functions as a repository for this information. For example, in my home state of Massachusetts, the Natural Heritage & Endangered Species Program maintains a number of thoughtfully prepared data sheets on the needs of species that are state-listed in one category or another. For instance, the 13 pages of guidelines for Blanding's turtle *(Emydoidea blandingii)* include data on habitat requirements, distances moved, and many other relevant information, along with nearly three pages of references from the scientific literature (The Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, "Guidelines for Protecting Blanding's Turtles and Their Habitats.") Unfortunately, this wonderful information is not easy to find, even when looking at the Program Web site. My sense is that there is a tremendous wealth of information like this that government agencies and NGOs have created, but that it is sprinkled far and wide and difficult to find.

On a much larger scale, NatureServe, an NGO spin-off of The Nature Conservancy and its network of natural heritage programs, has developed an extensive database of information on the plants and animals of North America (and a separate database for Latin America). NatureServe's databases contain large amounts of information on the biology of individual species and many references to the primary literature. They include rankings of conservation status, such as endangered species listings from the U.S. Fish and Wildlife Service, listings from Canada's Committee on the Status of Endangered Wildlife in Canada, rankings from the World Conservation Union (IUCN), and NatureServe's own state and province rankings, although they do not give the official status of species as listed by individual states. NatureServe offers good information on taxonomy (including discussions of whether a taxon is a truly distinct species, a subspecies, or merely a disjunct population), threats, geographic range, and management concerns. The organization has devoted a tremendous amount of work to create accurate, well-researched write-ups for each species.

It appears that there are many great resources available, but most of them are quite difficult to find. It would be extremely useful to have central access to the high-quality detailed conservation materials that have been created by governmental and NGO groups. I would like to see a single repository with a solid core of information, supplemented by links to detailed documents produced by other organizations. If NatureServe were willing to serve this function, they already have a superb foundation of information on many thousands of species; adding links to other resources would certainly require a fair amount of vetting, but would be very worthwhile.

Producing Resource Materials on Conservation Topics.

Conservation agencies, both governmental and NGO, are almost invariably understaffed. It appears that university students, when carefully supervised, represent a major resource that is just beginning to be tapped. Like a number of other institutions, Brandeis University, where I teach, has a very active environmental internship program that places advanced undergraduates with a variety of different environmental organizations, including conservation groups. In these positions (either summer or term-time) a number of interns have created excellently researched reports, including a major document on exotic species of Massachusetts that was sponsored by The Nature Conservancy.

As an alternative to placing interns individually with organizations, a couple of universities have students researching and writing standardized reports that are widely used. In the largest such program I know of, Phil Myers, a Professor of Ecology and Evolutionary Biology at the University of Michigan, has enlisted vast numbers of students in developing very solid, in-depth materials about the world's animals for his Web site, the "Animal Diversity Web" (http://animaldiversity.ummz.umich.edu/site/index.html).

It would be extremely useful to have central access to the high-quality detailed conservation materials that have been created by governmental and NGO groups.

I would suggest creating workshops or charrettes that bring conservation biologists and planners together to jointly focus on current issues in their region.

In a similar vein, my students have been producing extensive reports on ecoregions of the US and Canada, plus a few overseas ecoregions. Based on the ecoregion boundaries delineated by the World Wildlife Fund-US, these 40-50 page reports give background on each region's biodiversity, threats to that biodiversity, and responses to those threats. I am in the process of making the best of these reports available on the Web, to make them freely accessible. It is clear from projects such as Animal Diversity Web and my students' ecoregion reports that using bright undergraduates to perform careful library research and then create cleanly edited synthesis reports has tremendous potential. I believe that—when properly supervised—these students can produce reports of great value for conservation and planning organizations. I am beginning to explore having students create reports on demand, asking governmental agencies and NGOs about their needs and then creating solid reports for them. Any of these models have real potential for planners: interns to perform research on demand, teams that produce libraries of reports, or teams that create reports on demand.

Where can planners and conservation biologists come together and work jointly? Why are the basics of each field so foreign to each other?

Conservation biology is a highly interdisciplinary field, yet all too many conservation biologists remain largely isolated from their colleagues in the planning field. I would not recommend creating yet another society and journal to bring these groups together—there are already too many journals and annual meetings to be kept up with. But we need to find mechanisms to bring these two groups together.

The workshop for which this publication was prepared is an excellent model for helping the two groups learn from each other. In the past I have offered courses in which I share my understanding of conservation biology with practicing planners, and these have been well received. Rather than working within a course framework, however, I would suggest creating workshops or charrettes that bring conservation biologists and planners together to jointly focus on current issues in their region. It is critical that both groups begin to learn the language and problems that the other group of professionals uses, and I believe that this will best be achieved by addressing real-world situations.

During the first such charrettes, it will be important to keep the stakes low—these should not be high-pressure situations from which a complete and detailed plan is expected to emerge, ready to be put into place on the landscape. Instead, if at all possible, the early charrettes should be an opportunity for disparate players to describe the questions that they would raise in working on a given problem, along with the tools that they would employ in attempting to tackle it. As the series of charrettes progresses, the situations being discussed can become more immediate so that the plans can have real impact.

If possible, it would be good for a regional planning board to convene these charrettes; they would have access to good data and would in many cases have the regulatory authority to put combined conservation/land use plans into action. My hope is that over time, with added experience, planners will begin to ask questions that conservation biologists might raise, and vice-versa; each group will begin to think a little bit like the other.

Conclusions

Conservation biologists and ecologists are trained to think as scientists, and typically consider themselves scientists. Despite their strong backgrounds in ecology, and their understanding of the world's complexity and variability, it is difficult for them to avoid the underlying scientific mantra that society's problems have discrete technical solutions, and that science is the primary tool to help solve problems. Moreover, conservation biologists are passionate about their subject; they believe that the world's biodiversity is deeply threatened, and they want to do what they can to help. When approached by planners seeking guidance about how to effectively protect biodiversity, we conservation biologists would like to offer clear, explicit answers. Yet we cannot simply say: "Salamanders need 600 feet of upland buffer around their vernal pool breeding habitats," or "Conservation corridors should be at least 300 feet wide." Situations in nature are too variable (in space and time and especially between species) for conservation biologists to make such definitive statements.

Accumulating knowledge of the ecological needs of different organisms is a slow and labor-intensive process; in addition, as indicated earlier, there are no general rules for calculating the needs of organisms. In general, the recommendations that conservation biologists make to land use planners and regulators have to be based on empirical studies of specific organisms. Both conservation biologists and land use planners have to recognize the limits of science-based information. While I am a very strong believer in the importance of scientifically determining how to keep native species and ecosystems healthy, I also think that (1) land use planners have to acknowledge that conservation biology and ecology are among the very most historical and idiosyncratic of all sciences, so that findings in one region or from a certain time will not necessarily apply in other locations or times; and (2) conservation biologists have to acknowledge that the problems they are addressing are not purely scientific in nature, and that many stakeholders need to contribute goals and expertise. Equipped both with the tremendous knowledge that ecologists and conservation biologists have accumulated over recent decades and with recognition that conservation biology responses must almost always be tailored to the particulars of a specific situation, I believe that planners and biologists will be able to help protect our biodiversity heritage well into the future.

Literature Cited

Dixon, J. D., M. K. Oli, M. C. Wooten, T. H. Eason, J. W. McCowan, and D. Paetkau. 2006. Evaluating the effectiveness of a regional corridor for the Florida black bear. *Conservation Biology*. 20:155–162.

Dobson, A., K. Ralls, M. Foster, M.E. Soulé, D. Simberloff, D. Doak, J.A. Estes, L.S. Mills, D. Mattson, R. Dirzo, H. Arita, S. Ryan, E.A. Norse, R.F. Noss, and D. Johns 1999. Corridors: Reconnecting fragmented landscapes. In *Continental Conservation: Scientific Foundations of Regional Reserve Networks*, M.E. Soulé and J. Terborgh, eds., pp. 129-170. Island Press: Washington, DC.

Gadgil, M. Personal communication, April, 1998 at the Biodiversity Conservation Prioritisation Program conference in New Delhi.

Guikema, S. and M. Milke. 1999. Quantitative decision tools for conservation programme planning: practice, theory and potential. *Environmental Conservation.* 26:179–189.

Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife. "Guidelines for the certification of vernal pool habitat." http://www.mass.gov/dfwele/dfw/nhesp/vpcert.pdf. (Accessed February 27, 2007.)

Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife. "Guidelines for protecting Blanding's Turtles and their habitats." http://www.mass.gov/dfwele/dfw/nhesp/nhprot_blandings.pdf. (Accessed February 27, 2007.)

Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries and Wildlife. "Guidelines for protecting rare species and their habitats." http://www.mass.gov/dfwele/dfw/nhesp/nhspguid.htm. (Accessed February 27, 2007.)

Perlman, D. L. and J.C. Milder. 2005. *Practical Ecology for Planners, Developers, and Citizens.* Washington, DC: Island Press.

Perlman, D.L. and G. Adelson. 1997. *Biodiversity: Exploring Values and Priorities in Conservation*. Cambridge, Massachusetts: Blackwell Science.

Pressey, R.L., C.J. Humphries, C.R. Margules, R.I. Vane-Wright, and P.H. Williams. 1993. Beyond opportunisms: Key principles for systematic reserve selection. *Trends in Ecology and Evolution*. 8:124-128.

Regosin, J. V., B. S. Windmiller, R. N. Homan and J. M. Reed. 2005. Variation in terrestrial habitat use by four pool-breeding amphibian species. *Journal of Wildlife Management*. 69(4):1481-1493.

U.S. Fish and Wildlife Service. 2005. "Barton Springs Salamander (*Eurycea sosorum*) Recovery Plan." U.S. Fish and Wildlife Service, Albuquerque, NM. http://ecos.fws.gov/docs/recovery_plans/2005/050921.pdf (Accessed February 28, 2007.)

Wilson, K.A., M.F. McBride, M. Bode, and H.P. Possingham. 2006. Prioritizing global conservation efforts. *Nature*. 440:337-340.

Bridging the Gap: Incorporating Science-Based Information into Land Use Planning

Bruce A. Stein, Ph.D., NatureServe

Introduction

Land use planning, in one form or another, has been occurring since the colonization and establishment of the United States. Historically, planning has tended to focus on the allocation of land and other resources in a way designed to balance the protection and advancement of societal values, such as community health and well-being, with the rights of land owners to use and benefit from their holdings. Incorporating ecological considerations into this planning balance was a fairly late arrival on the scene, marked in a serious way by Ian McHarg's 1969 landmark book Design with Nature. This generally coincided with the public's broader interest in environmental protection, resulting from such things as the broad indictment of pesticides contained in Silent Spring (Carson 1962), an oil spill dirtying beaches in Santa Barbara, smog enveloping the Los Angeles basin, and chemical pollutants igniting on the Cuyahoga River. The launch of the modern environmental era was subsequently formalized in public policy through passage of milestone federal legislation, such as the Clean Water Act, Clean Air Act, and Endangered Species Act.

While some in the scientific community had long been involved in studying the effects of land use and other human activities on what is now known as biological diversity, most scientific work hewed closely to traditional disciplinary lines. Ecological researchers often worked specifically to avoid human influences, seeking to examine organisms or ecosystems untainted by interference from people. As an example, the Ecological Society of America's Committee on the Preservation of Natural Conditions — the predecessor to The Nature Conservancy — was chartered originally to identify pristine areas where ecological research could be carried out unhindered by human influence. Indeed, a difference of views as to whether that committee should retain a strict focus on research, or become more involved in preservation efforts and environmental advocacy, was at the root of its split from ESA and the eventual formation of the Conservancy.

Following the public's awakening to the environmental crisis, during the 1970s environmental science began to be recognized as a legitimate discipline in the nation's colleges and universities. It was not for another decade, however, that the discipline of conservation biology was formalized (Soule and Wilcox 1980). Unfortunately, academic traditions, at least in the life sciences, tended to discourage students and faculty from entering fields such as conservation biology that are perceived as having an "applied" rather than "basic" science focus. Work with practical applications often held a stigma that was not helpful for academic career advancement. As a result, conservation-oriented biologists often carried out their work as an addendum to a more mainstream research agenda, or left academia to work in government agencies, non-profit organizations, or private consulting firms.

The pendulum is now swinging in favor of recognizing the academic value of scientific research that has applied conservation value. The Society for Conservation Biology is now one of the fastest-growing professional societies, with more than 10,000 members around the world. Even the National Science Foundation, the primary federal funding source for non-medical life-science research, has adopted new proposal review guidelines that both recognize and encourage the broader impact of research, including its use for informing environmental protection and conservation efforts.

Despite the convergence in ecological interests over the past few decades between the land use planning community and the conservation science community, a considerable gulf still exists between the two groups. Many land use planning decisions still only incorporate ecological principles and biodiversity considerations in a cursory way, if at all. And many conservation scientists are still largely disconnected with how their research could have real-world application. What are the reasons for this continued disconnect, and what barriers exist that inhibit better integration of science-based information into the land use planning process? Conversely, where is the process working, and what opportunities are available for broadening such interaction and integration?

What are the most significant barriers to the integration of science-based information into land use planning?

At the heart of this disconnect are different cultural norms that characterize the two communities, exacerbated by differing communications styles. Land use planning involves the identification and balancing of multiple values — social, economic, and environmental — and usually takes place within a political framework where compromise is the norm. The scientific method places a premium on objective facts, and while a given hypothesis technically can only be disproved rather than proved, the focus is generally on identifying the "right" answer. Ideas and analyses are expected to stand or fall on their merits, and compromise is not a part of the scientific tradition. As a result, many natural scientists engaged in environmental management or planning processes are surprised (and often offended) when their fact-based "solution" is modified or ignored altogether.

In part, this is a result of different views of the role of science in public policy. Despite the popular notion that science drives decision-making, it is clear that even under the best circumstances science informs but does not dictate policy. Rather, scientific evidence serves as one of several inputs. This is most evident in the field of risk assessment, where scientific studies may quantify environmental degradation or human health effects (e.g., number of deaths), but these factors are weighed against economic cost and other social values in the development and adoption of policies and regulations. And ultimately, these factors are balanced within a political context.

Differing Values

In many ways, the issue is less about the role of science, and more about conflicts, real or perceived, among values. For instance, while there is an emerging body of knowledge that demonstrates that healthy ecosystems are important to long-term sustainability and economic prosperity (e.g., Millennium Ecosystem Assessment 2005), the classic clash among values gets simplistically articulated as "jobs versus environment." A more nuanced conflict in values is even emerging within the smart-growth community. Smart growth is generally viewed as a more environmentally sustainable and socially responsible development style than traditional land use patterns. Nonetheless, different stakeholders within the broader smart-growth community may value different things — say, open space protection or affordable housing — which at times can represent conflicting goals.

Understanding the values that different parties bring to the table is not always straightforward, since people often are not clear or honest about their own underlying values. This lack of transparency can complicate efforts to better incorporate science-based information into planning processes, and can undermine trust relationships. Because many in the conservation biology field come to the profession out of a profound sense that too much of our natural world already has been lost, they often bring an implicit set of values that focuses on the protection or preservation of natural features. While this may be a perfectly rational (and indeed, laudable) set of values, working productively with planners who are attempting to balance a variety of values requires that, at a minimum, this be made explicit. It also means that conservation scientists must be willing to constructively engage with parties that hold very different values in order to ensure that ecological considerations get incorporated into economic and social decisions.

Conservation scientists must be willing to constructively engage with parties that hold very different values in order to ensure that ecological considerations get incorporated into economic and social decisions.

Uncertainty and the Dynamic Nature of Ecosystems

The nature of scientific uncertainty creates another barrier to collaboration between planners and scientists. While uncertainty exists in all aspects of business, the development process thrives on certainty and tries to avoid surprises. Unfortunately, our scientific understanding of the natural world is imperfect, and even what we do know often comes with large caveats. Planners and other policymakers are often looking for definitive answers, when scientists can often only provide qualified guidance. Even the language used to describe uncertainties can be a major impediment to clear communication across communities. Expressing uncertainty and error bounds is good scientific practice, and is a means of quantifying the accuracy and reliability of information. To users in the planning and other communities, however, the focus on uncertainty can have the oppo-

Planners and other policymakers are often looking for definitive answers, when scientists can often only provide qualified guidance.

site effect, undermining rather than strengthening reliability, even when strong evidence exists.

A related barrier has to do with static versus dynamic notions of the natural world. Conservation scientists increasingly view natural processes as highly dynamic, responding not only to long-recognized ecological factors, such as succession, but to a host of new forces, including the spread of alien species and global climate change. And while biodiversity science historically has focused on documenting what exists, how species interact, and how ecosystems function, the science is actively moving towards a predictive and forecasting mode. As a result, conservation scientists generally have moved away from equilibrium-based models of natural stability (the so-called "balance of nature"), and are focusing more on understanding such things as natural ranges of variability and landscape-scale processes. Recognizing the dynamic nature of ecosystems is at the heart of the scientific communities' general unease with the "no surprises" policy for Endangered Species Act implementation.

Most land use plans still have a fairly static view of the landscape, assuming that in the absence of direct human intervention, what currently exists on the landscape will continue to exist. Interestingly, incorporating dynamic change models into planning efforts is actually something that is routine. Traditionally, however, these models have focused on projections of such factors as population growth and economic performance, rather than ecosystem change. An example of how dynamic ecosystem processes are important for planning relates to vegetation dynamics and fire management in the so-called "urban-wildland interface." As increasing numbers of homes are being built in and abutting naturally vegetated wildlands, long-term changes in vegetation structure have implications for such public safety issues as fire protection. Indeed, the very presence of homes in formerly unpopulated areas can constrain the use of fire management for vegetation maintenance, leading agencies instead to focus exclusively on fire suppression. In turn, such suppression efforts can lead to an unhealthy build-up of fuels, degraded wildlife habitat, and the potential for catastrophic conflagrations from both public safety, economic, and ecological perspectives.

Local Capacity

The scale at which most planning is carried out represents yet another challenge. Land use planning in the United States largely takes place at the local level, through county planning departments and city and township planning offices and commissions. While some of these planning offices are extremely sophisticated, particularly in large, wealthy jurisdictions, many local planning offices have small professional staffs or are run by volunteer commissioners. As a result, in many places planning staffs have relatively limited expertise in ecological sciences and limited capacity to maintain and run sophisticated software tools. The combination of a large number of such planning offices (there are more than 3,000 counties alone in the United States), and the small size and limited capacity in many of these creates an additional barrier to the incorporation of science-based information into the planning process.

Compounding this is the general lack of purpose-built tools and information products designed specifically to help planners understand and access relevant ecological information, and to analyze that information in a way that meets their specific needs. Many of the existing tools and scientific databases have been developed by scientists primarily for use by other scientists, and lack the type of cross-community translation and outreach functions needed to meet the needs of the planning community's large and geographically diffuse constituency. As a result, many planning offices rely on environmental consulting firms for the expertise to address ecological issues when the need arises. And while such firms may provide high-quality service, due to cost and other considerations they usually are only engaged in special circumstances, losing the opportunity for ongoing incorporation of biodiversity and ecological considerations into routine planning decisions.

What are the most significant opportunities for advancing the integration of science-based information across communities?

Despite the barriers that exist, a great deal of progress is being made in increasing the degree to which ecological information is being incorporated into the land use planning process. The divide between the planning and conservation science communities increasingly is being bridged by individuals and projects that are committed to understanding the other's needs. In part this reflects a maturing of the conservation science community, and a greater willingness of many scientists to get involved in the lengthy and often frustrating planning processes that end up shaping much of our natural landscape. It also reflects the planning community's response to an increasing interest among the public in open space, and its link to quality-of-life issues. Indeed, one of the most impressive political trends of the last decade has been the large number of bond issues passed at state and local levels, in which citizens are opting to increase taxes in order to protect habitat and preserve other open space.

Another major policy shift is at work that is encouraging greater collaboration and integration at the local level. The policy framework for conservation and environmental management is increasingly moving from the top-down, "command-and-control" regulatory approaches that were initially adopted to deal with such issues as water and air pollution, toward more flexible outcome- or incentive-based approaches that often include local involvement. Regulatory approaches have been extremely successful in dealing with certain types of problems, and will remain needed and relevant. Other problems, ranging from non-point source water pollution to the cumulative impacts of habitat fragmentation on wildlife, have proven to be resistant to top-down command-and-control approaches. As a result, emphasis is now increasingly being given to empowering local communities to be creative about the way that they bring diverse stakeholders together and solve problems.

As an example of this approach, Washington State's Nisqually River is the focus of a locally based effort designed to sustain ecosystem health and promote economic vitality in the region. The Nisqually River Council has served as an umbrella for a host of watershed-based recovery activities, while local groups such as the Stewardship Partners have successfully enlisted broad-based landowner and citizen support for watershed activities. Such locally based efforts involving planners, scientists, farmers, ranchers, and environmentalists, among others, was at the heart of an August 2005 White House Conference on Cooperative Conservation (CEQ 2005). A notable element of many of the successful initiatives highlighted at that conference was the close collaboration between scientists and planners, and the way in which scientific data, tools, and expertise were brought to bear in the planning and implementation of these efforts.

Data

The availability of reliable data is essential for helping to incorporate biodiversity considerations into planning processes. When dealing with a contentious project, clearly separating the fact base from the interpretation of those facts can help clarify where issues exist, and where they don't. Detailed mapping of a sensitive ecological feature, for example, will sometimes reveal that a potential conflict is not as serious as initially thought, providing more options for resolving the problem.

Basic types of data relevant to this need include information about the species and habitats that exist in a region, their condition or conservation status, the location of sensitive or other important features, and how these resources are likely to be affected by proposed activities. Fortunately, there are some excellent sources of data that are directly relevant to the needs of the planning and environmental management professions. For more than thirty years, state natural-heritage programs have focused on gathering biological data for use in land planning and resource management. By carrying out inventories and managing their data according to consistent national standards, these programs offer planners a reliable source of detailed data on plants, animals, and ecological communities in each state, with particular focus on those of conservation concern.

NatureServe, a non-profit organization that provides national coordination and technical support for these programs, integrates much of this data into a national view that can be accessed online through the NatureServe Explorer website (www.natureserve.org/explorer). Building on these core biodiversity databases, an increasing number of natural-heritage programs are developing planner-friendly analytical products that map out environmentally sensitive areas. The Massachusetts BioMap project, for example, identifies sensitive biodiversity

The divide between the planning and conservation science communities increasingly is being bridged by individuals and projects that are committed to understanding the other's needs.

Despite the ever-increasing amounts of information and the analytical tools available to planners, putting these to work still fundamentally requires human interpretation and application.

areas statewide, and has established a program designed to work with local planning offices in the application of these maps and the underlying data (Massachusetts Natural Heritage and Endangered Species Program 2001).

State- and regional-scale conservation plans have been a particular focus of activity in recent years, and these plans provide important ecological context for planners. Federally funded State Wildlife Action Plans were completed for all states in 2005, and should serve to help chart the course of wildlife conservation efforts across the country. All of these plans identify animal species in need of special attention, and many include maps of priority habitats or areas for wildlife conservation. Another important effort has been The Nature Conservancy's work to identify and map out important biodiversity areas within each ecoregion of the country. These "ecoregional plans" offer another view of conservation priorities, and have the advantage of including both plants and animals of conservation concern. Still another regional planning approach focuses on what is variously termed green infrastructure, or green-printing. Such green-printing plans generally focus on identifying major remaining habitat areas, together with existing or potential connections among these core areas. Green prints can cover a single state, such as Maryland (www.dnr.state.md.us/greenways/greenprint/), or can include multiple states, as in the case of EPA's Southeastern Ecological Framework (http://www.geoplan.ufl.edu/epa/).

A variety of other data sources exist within individual states, although locating these sources can sometimes be difficult. Links to other state-based sources of information can be found through the NatureServe website (www.natureserve.org), Defenders of Wildlife's Biodiversity Partners website (www.biodiversitypartners.org), and through the U.S. Geological Survey-sponsored National Biological Information Infrastructure (www.nbii.gov).

Tools

A variety of technological tools now available to planners, some generic and some purpose-built, make ecological data, analyses, and expertise more accessible than ever before. It is hard to overstate how the Internet has revolutionized and democratized access to information in just over a decade. Not only is the Web the primary means for scientists to communicate and share findings, but it provides planners in offices large and small with access to resources once available only to the privileged few. While the first generation of web-based resources took the form of static documents or information products, a new generation of mapping and visualization tools is now being deployed online. The current tools mostly provide opportunities to view the landscape (e.g., Google Earth), as well as to add user-defined features. It will not be long, however, before fully web-enabled analytical GIS packages are available through this medium. The Web also has proven to be a social force, fueling the emergence of numerous virtual communities that address a variety of scientific and planning-related issues, and providing unprecedented opportunities for citizen participation in scientific endeavors and planning processes.

Several important concepts emerge in considering how technology can enable the integration of scientific information into planning processes. Transparency and accountability are key for information and analyses to be credible, and to stand-up to legal and political scrutiny. Such transparency is essential to create a trust relationship among parties that may have divergent and strongly held views and values; "black-box" solutions can undermine this trust. Because planning involves a balance among competing values, analytical tools should allow explicit recognition of the values underlying them, or accommodate different value sets. Finally, identifying alternative scenarios for meeting ecological needs, if possible, is preferable to producing a single "right" answer. Such alternatives allow planners flexibility where possible, and conversely show where there is little or no "wiggle room." A whole class of optimization techniques are becoming available to help evaluate the efficiency and effectiveness of these alternatives, and to help users decide among them.

NatureServe Vista is an example of a decision-support tool specifically designed to help incorporate biodiversity considerations into land use planning (www.natureserve.org/prodServices/vista/overview.jsp). This GIS-based software allows a user to map out the biological features in their area of interest. Based on the condition and distribution of these features (and confidence in the source data), a "conservation value" landscape can be generated that displays areas of greater and lesser importance or sensitivity. In calculating this conservation value, the tool allows users to select and weight different classes of features depending upon their particular interests, requirements, or values. For instance, a user may choose to limit the analysis to legally protected species, or might wish to include a fuller array of species and habitats of conservation interest. With a basic understanding of how these features are distributed across the landscape, a user can then evaluate how alternative plans or proposals would affect biological features of interest, or examine the relative significance of a given site or tract of land.

A number of more general land use planning decision tools are also available, such as CommunityViz from the Orten Family Foundation (www.communityviz.com/). This GIS-based tool provides a means to visualize analyses of land use alternatives, and to understand their potential impacts from environmental, economic, and social perspectives. Through the use of 3-D simulation, scenarios can be visualized from different angles, a feature that promotes citizen participation in planning processes. As with the Internet, this approach helps to realize the Jeffersonian ideal of participatory democracy by enabling broader understanding, dialogue, and participation.

Expertise

Despite the ever-increasing amounts of information and the analytical tools available to planners, putting these to work still fundamentally requires human interpretation and application. As a result, many of the solutions for breaking down barriers to the use of scientific information in land use planning must involve building human capacity and expertise. In fact, with the Internet providing a conduit for vast quantities of unfiltered information, the need for knowledgeable people to parse this into useful bits will only increase.

Development of a cadre of cross-trained conservation scientists and planners — individuals who are capable of bridging the divide between the two worlds — is a particular need. Scientists must learn to translate their concerns and findings into language that can be readily assimilated by non-specialists in the planning professions. This does not necessarily mean "dumbing down" such works, but rather taking the time to clearly express relevant information in a scientifically sound yet publicly accessible manner. The Environmental Law Institute's Conservation Thresholds publication (Kennedy et al. 2003), which gave rise to the present publication and conference, is an excellent example of translating research results into a form that is intelligible and meaningful for a planning audience. Similarly, there is a need for planners to become more conversant in the language of the ecological sciences, both to help interpret and highlight important trends for their profession, and to provide input to the scientific community in terms of what would be useful for the planning profession.

Our experience at NatureServe over the years in providing biodiversity data to inform land use planning is that there is no substitute for one-on-one interaction with prospective users of the information. Often users know that they have an issue, but are unsure what the relevant questions are that they should be asking. Or they may know they have a need for data, but are either unaware of what exists, or what is appropriate for addressing their need. This is particularly true at the local level, where many planning offices are small, and staffed with individuals that must cover a wide range of activities. Several natural-heritage programs, including those in Virginia and Massachusetts, have established local liaison offices to help such jurisdictions understand what is available and how to apply it to meet their local needs. Other programs, such as those in Pennsylvania, Minnesota, and Colorado, have county inventory programs underway that work with individual counties to map out sensitive ecological resources and provide specific information and advice.

Development of a cadre of cross-trained conservation scientists and planners — individuals who are capable of bridging the divide between the two worlds — is a particular need.

Bridging the Gap

While barriers still exist between science and public policy, there are a number of developments that promise to bridge or shrink those gaps. Key to this is the growing public interest in maintaining quality of life, and the role that natural lands and open spaces play in this pursuit. To the degree that citizens have an expectation that wildlife conservation and open-space preservation are a part of their communities, the planning profession is likely to respond to these desires. And fortunately, there is an expanding suite of data sources, tools, and expertise available to planners to help inform and guide land use and natural-resource-management decision-making.

Land use planning is a process that takes place in the context of strong political, economic, and social currents, and there will always be contentious issues that arise out of competing values. The role of science is not to provide the answer in these situations, but rather to ensure that the issues are addressed and decided on a fair and level playing field. Traditional planning processes have long focused on what is referred to as “gray infrastructure” — roads, sewers, and other aspects of the built environment. The challenge is to ensure that biodiversity and other components of “green infrastructure” are actively and routinely considered as part of this process. Nearly forty years since the publication of Design with Nature, we are beginning to make real progress toward that goal.

Literature Cited

Carson, R. 1962. Silent spring. Boston: Houghton Mifflin.

Council on Environmental Quality (CEQ). 2005. Faces and Places of Cooperative Conservation: Profiles in Citizen Stewardship. Washington, DC: White House Council on Environmental Quality, Washington, DC.

Kennedy, C., J. Wilkinson, and J. Balch. 2003. Conservation Thresholds for Land Use Planners. Washington D.C.: Environmental Law Institute.

Massachusetts Natural Heritage and Endangered Species Program. 2001. BioMap: Guiding Land Conservation for Biodiversity in Massachusetts. Boston: Commonwealth of Massachusetts.

McHarg, I. 1969. Design with Nature. Garden City, NY: Natural History Press.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Synthesis. Washington, DC: Island Press.

Soulé, M. E. and B.A. Wilcox. 1980. Conservation Biology: An Evolutionary-Ecological Perspective. Sunderland: Sinauer Associates, Inc.

Ecology and New Directions for Land Use Planning: Barriers and Opportunities to Change

Philip R. Berke, Ph.D., University of North Carolina

Species extinction and biodiversity loss take several forms, but much of it results from unfettered urban expansion. The sobering fact is that ecological decline is not unexpected. As urban growth accelerates across open landscapes, the potential for extinctions and biodiversity loss escalates accordingly. At the same time, advances in technologies for mapping land use, revised understanding of the relationships between urbanization and ecological disturbance, and new thinking about compact urban form have increased opportunities to integrate ecological knowledge into land use decision-making.

Conservation specialists increasingly emphasize the importance of having a pro-active land use planning program designed to avoid ecological loss, rather than simply reacting only after significant and often irreversible loss has occurred. Such a program can be broadly construed to include not just a comprehensive plan, but also plan implementation techniques that include various regulations, incentives, and capital improvement investments used to guide the location, density, mix, design, cost, and rate of development. This approach prevents development that causes ecological loss in the first place, or ensures that if loss does take place at a given site, it must be minimized and restored within the same ecological setting

While land use planning is a potentially effective long-term solution to future ecological decline, research-based evidence indicates that existing land use plans are too weak to encourage development that recognizes ecological systems. In addition, public apathy and a lack of political will may also hamper conservation planning efforts. In fact, communities sometimes adopt public land use policies that unwittingly encourage loss. This paper identifies major barriers to applying sound landscape ecological principles to local land use planning programs, and recommends potential changes to land use practices that would encourage local governments to take action. When possible, I draw on research that examines the validity of these barriers and adequacy of the potential changes to facilitate local response to protect landscape resources.

What are the major barriers to applying ecological science-based information to land use planning?

Weak Plans and Ordinances for Ecological Protection

Several researchers have documented successful examples of how individual communities integrate ecological science-based data and protection policies into local planning (Beatley 2000, McElfish 2004, Perlman and Midler 2005). However, only a few communities have integrated specific, well-developed ecological protection provisions into their local plans and development ordinances. The limited number of studies that have evaluated cross-sectional samples of local planning programs report that these programs do not take a balanced, holistic approach to guiding development and protecting natural resources (for example, Berke and Manta-Conroy 2000, Brody et al. 2003a, 2003b, Godschalk et al. 1989, Kaiser and Davies 1999, Norton 2005). Berke and Manta-Conroy (2000) examined how well six core values of sustainable development are supported by thirty high-quality comprehensive plans (most of which have received awards from national or state chapters of the American Planning Association). These values include:

- *Harmony with nature.* Land use activities that support essential cycles and life support functions of ecosystems (e.g., maintenance of water quality, reduction of flooding, and enhancement of sustainable resource development).
- *Livable built environments.* Land use designs that focus on "sense of place" in the form of social cohesion, attractive buildings, safety, accessibility to a mix of land uses, and visually pleasing landscapes.
- *Place-based economy.* Local economic activity that operates within natural system limits and meets local needs.
- *Equity.* Land use patterns that provide equitable access to social and economic resources and healthy living environments.
- *Polluters pay.* Those who cause pollution bear the costs.
- *Responsible regionalism.* Communities that minimize harm to other jurisdictions in pursuit of local goals.

Berke and Manta-Conroy found that “livability” values come through most strongly in the historic mainstream focus of comprehensive plans (Kaiser et al. 1995, Kent 1990). In contrast, the remaining five core values receive considerably less attention. Environmental elements of plans, for example, give more attention to “livability” values than to “harmony with nature” values: emphasis is placed on sense of place, living close to nature, and supporting neighborhood parks and greenways to improve urban livability, while significantly less attention is given to the hydrological, nutrient, and wildlife flows that are inherent to landscape ecological integrity.

Studies of how well watershed protection concerns are integrated into local comprehensive plans in forty-five communities in South Florida (Brody et al. 2003b) and ninety communities in North Carolina (Kaiser and Davies 1999) indicate poor plan quality. Several dimensions of the plans were evaluated, including, for example, strength of the fact base, breadth of goals, the degree to which policies address inter-jurisdictional coordination, and specificity of plan implementation actions. In particular, the fact base involving the application of watershed science-based information was found to be the weakest dimension. In Florida, this finding was particularly surprising, given the presence of a major federal initiative to restore the Everglades and a strong state program that supports ecosystem and regional watershed management (Brody et al. 2003a). Other studies, based on cross-sectional samples of local plans and plan implementation practices (e.g., land use regulations, incentives and investments) aimed at wildlife habitat and wetland protection (Brody et al. 2006), coastal zone management (Norton 2005), and mitigation of natural hazards (Berke and Beatley 1992, Burby et al. 1985, Godschalk et al. 1989), offer similar conclusions.

These studies demonstrate a general lack of local application of science-based information in the fact base of local plans and implementation practices. They reveal a limited local knowledge about existing resources, human impacts to these resources, and their management status. This finding was consequential, as goals and policies in plans and standards in ordinances were found to be weak. A thorough understanding and inventory of the state of natural resources to be managed is an essential ingredient to crafting strong plans and ordinances.

Land Use Management Paradox and Ecological Train Wrecks

A land use management paradox arises when communities adopt plans and plan implementation practices only after many of the critical natural resources they intend to protect have already been lost to development. Former Secretary of the Interior Bruce Babbitt aptly called these events “train wrecks,” because they stimulate protection efforts that are reactions to an ongoing ecological crisis — e.g., loss of seagrass in the Chesapeake Bay, water quality declines in the Everglades, loss of spotted owl habitat in the Northwest (Reinhold 1993, p. A1). While “train wrecks” could be avoided through sound planning, emerging research supports the existence of this pattern of community behavior to ecosystem threats. Controlling for community level socioeconomic factors and the capacity of local planning agencies to plan, Brody (2003a) found that high levels of biodiversity values in a cross-section of Florida communities do not stimulate communities to adopt high-quality plans and implementation measures that integrate ecosystem management principles. Despite the wide availability of detailed digital maps of biodiversity “hotspots” generated by the state fish and wildlife agency, Brody found that the local comprehensive plans in jurisdictions with high biodiversity levels had a strong fact base (e.g., inventory of resource base, assessment of urban development trends) and detailed policy statements that address natural resource protection only when communities were directly threatened by urban development. Without the threat, communities with high biodiversity levels had weak plans.

The land use management paradox is not a new phenomenon. Over two decades ago, a national study of over 1,200 local floodplain management programs revealed that communities only adopt strong floodplain management plans, regulatory ordinances, and hazard land acquisition measures after a disaster or intensive floodplain development had already taken place (Burby and French 1981, Burby et al. 1985). These communities tended to adopt hazard mitigation practices in reaction to the problems, rather than proactive actions designed to avert loss of the mitigation services of floodplain natural resources (e.g., flood mitigation functions of riparian buffers and wetlands), or human life and property. The paradox emerges since communities acted only after development had already occurred, causing these practices to be much less effective in accomplishing planning goals.

These studies suggest that there is a low level of commitment for proactive planning to protect critical natural resources. Without the warning signals of habitat fragmentation, loss of biodiversity, and water quality decline, communities lack ample motivation to take action.

Spatial Mismatch Between Local Governance and Regional Landscapes

A spatial mismatch exists between the scale at which local governments need to plan and manage to effectively protect landscape ecological resources, and the scale at which land use planning and decision-making is traditionally carried out. This mismatch is apparent in metropolitan regions throughout the U.S., where a tradition of home rule and localism dominates amid landscapes and ecosystems that require thinking and planning on larger ecological scales. Numerous fragmented and overlapping local governments, regional authorities, special districts, state agencies, and even federal agencies make separate decisions about land development and conservation in metropolitan areas. Even metropolitan Pittsburgh, for example, a moderate size metropolitan region of 2.3 million people, contains 330 local governments – 5 counties, 184 municipalities, and 141 townships, not to mention other entities that influence land use (e.g., sewer and water authorities and dozens of school districts) (Daniels 1999).

This mismatch has significant consequences. First, local governments in metropolitan areas direct too much of their landscape management effort toward identifying and protecting isolated patches of habitat, "postage stamps" that often become surrounded by development and have questionable long-term ecological viability (Beatley 2000). This approach fails to take advantage of existing natural areas by connecting existing patches and corridors that may span across jurisdictional boundaries. Doing so would help to weave these otherwise isolated patches into a larger regional landscape-scale system.

Second, fragmentation of regulatory authority over land use keeps local governments weak. With landscapes chopped into dozens or even hundreds of governing entities, many local governments are too small and have inadequate capacity to deal with the widening challenges of suburbanization and landscape ecosystem protection. Many regions are what Bruce Katz (2006) calls a patchwork quilt of "little box" governments with limited horizons. Many of these "little boxes," especially those at the urban-rural fringe, do not have adequate tax bases to support the capacity to plan, lacking automated land planning support systems and professional staffs with expertise in planning and ecological systems. In spatial terms, these little boxes artificially divide regions that otherwise would represent single, interconnected ecological communities, as well as social and economic communities. Such divisions complicate efforts to initiate cross-boundary data collection, cooperative planning, and coordinated decision-making within regions.

Recent research supports this concern. For example, Brody's (2003b) study of forty-five local plans within a common regional watershed – the Everglades of South Florida — found that both the land use and environmental elements of these plans did not recognize, or made only vague reference to, the trans-boundary nature of watershed ecosystems. Further, these plans did not contain provisions that indicate commitment to collaborating with other jurisdictions to manage these natural resources. Other studies also found that fractured local plans fail to include "responsible regionalism" policies that focus on inter-jurisdictional coordination to address land use, open space protection, and other issues with spillover effects (Berke and Manta-Conroy 2000, Kaiser and Davies 1999).

Third, government fragmentation exacerbates sprawl, which can further weaken local governments (Berube et al. 2005). Research shows that increased fragmentation correlates with decreased shares of office space within business districts, less centrality of development nodes in regions, longer commutes, more edge cities and more sprawl (Orfield 1997). In this context, fragmentation not only constrains coor-

A spatial mismatch exists between the scale at which local governments need to plan and manage to effectively protect landscape ecological resources, and the scale at which land use planning and decision-making is traditionally carried out.

A common failure of implementing local plans is the lack of indicators for monitoring and evaluating how well the plan policies achieve plan goals and objectives.

dinated planning to manage urban growth and protect landscapes, but also stimulates sprawl-inducing competition among multiple jurisdictions for desirable commercial, industrial, and residential tax bases (Orfield 1997).

What types of science-based information and technology would be most useful in supporting application of land use conservation tools to land use planning and ordinance drafting?

Indicators for Plan Performance and Reporting

Model best practices for identifying and developing accurate and reliable indicators of landscape ecological health should be developed and widely disseminated. An indicator is a measurement that provides a gauge of the state or condition of the natural environment (e.g., number of acres of forest cover, lake pH values), as well as social conditions (poverty rate, percent of population with access to transit) and economic conditions (e.g., number of jobs, household income). Indicators are sometimes confused with environmental standards, which instead serve as normative policy guidelines that regulate the effect of human activity upon the environment. Standards may specify a desired state (e.g., lake pH should be between 6.5 and 7.5) or a limit on alterations (e.g., no more than 50% of forest may be damaged).

Indicators are needed to monitor local conditions, evaluate the performance of plans and ordinances, communicate to the public and elected officials about cumulative losses (and gains) in the ecological, social and economic health of a community, and identify priorities for action. Indicators also serve as an early warning system that identifies potential environmental problems and triggers planning actions to avoid "train wrecks." Indicators can also gauge whether an environmental condition has achieved an environmental standard.

Methodological advances in measurement and data collection clearly suggest that our capacity to track and report on ecological conditions has come of age. Yet a common failure of implementing local plans is the lack of indicators for monitoring and evaluating how well the plan policies achieve plan goals and objectives. Indeed, monitoring and evaluation too often seem to be the forgotten stage in the planning process (Seasons 2003), even though they are considered essential to land use planning (Berke et al. 2006).

A promising trend for better integrating ecological indicators into local planning programs is the emergence of local efforts to develop indicators for sustainable development (Berke et al. 2006, ch. 15). One example is Seattle's comprehensive plan monitoring program that tracks trends related to the achievement of core plan goals to analyze whether the city is accommodating growth in the ways proposed by the plan. Another example is Santa Monica, California, which has monitored sustainability indicators since 1994. The city regularly publishes status reports to communicate indicator trends to the public, and tracks the effectiveness of the city's plan, which in turn helps specify needed revisions.

While the growing number of communities that use sustainability indicators is a positive trend, sustainability initiatives are sometimes backed by inscrutable science. Sustainability advocates sometimes point to highly uncertain and untested casual linkages between indicators. Anecdotal evidence reveals long, questionable chains of causation, such as claiming that increased child poverty leads to more crime, which leads to unsafe streets, which leads to fewer people walking and more driving, which leads to more paving and water pollution, which leads to a decline in salmon population. Another limitation involves the significant gap between data needs for the indicators proposed by technical and scientific experts, and the resource, time and technical limitations of many planning departments. Finally, indicator systems are often constructed without ties to local plans and planning. They may be developed in isolation from planning agencies, other government and non-government users, and interest groups that are affected by the results of indicator tracking programs. Lack of these connections in plan monitoring programs reduces the potential effectiveness of indicator programs for inducing needed plan revisions and conservation action.

The planning field also lacks information about scientifically sound indicators based on landscape ecological principles that can be readily incorporated into local plans. The recent publication by the Environmental Law Institute (2003), Conservation Thresholds for Land Use Planners, is a good example of how to translate the science of landscape ecology into land use standards (e.g., minimum acres of a habitat patch area, minimum proportion of suitable habitat needed to maintain wildlife populations, minimum widths of riparian buffers, and the distance that edge effects penetrate into habitats) that can be monitored by a straightforward and measurable set of indicators (e.g., number and total acres of habitat patches with a minimum acreage, percentage of total stream length protected by minimum width of buffer). More attention must be given to developing such landscape ecological standards, and cataloging and disseminating available data sources and developing guidelines on how to translate the standards into an indicator format for monitoring and evaluating land use plans. Also, more consideration must be directed toward finding and publishing innovative local applications of ecologically-based indicators to land use planning.

Guidelines for Incorporating Landscape Ecology Information into Planning Support Systems

There is a significant need for the development of guidelines to assess the effectiveness and usability of landscape ecological information in local governments' planning support systems (PSS). A PSS consists of computer hardware and software, information bases, and skilled staff members working to facilitate collective community planning and design (Klosterman 2001). Information on landscape ecology, population, and the economy, as well as land use, transportation and infrastructure systems, must be coordinated with public inputs to assess impacts and make decisions about individual development decisions and future land use scenarios, and to track progress toward long-range plan goals (Coburn 2004).

While planning support systems are an integral part of most local government planning programs, they rarely incorporate landscape ecological data. Brody (2003a), for one, found that only two out of thirty communities surveyed in Florida used widely available digital maps of landscape biodiversity in their local PSS to prepare land use plans. Yet other data sources related to transportation, urban land use, housing, socioeconomic census data, land parcel values, topographic features, and so forth are frequently used (Decker 2001). This gap greatly hinders local ability to make ecologically sustainable planning choices. The differences may be largely due to federal legislation; for example, almost all local governments in metropolitan areas must evaluate and assess the impacts of land use change on transportation systems under federal ISTEA legislation. Yet, the Endangered Species Act (ESA), which is the main federal law that deals with biodiversity and landscape ecology, has a much narrower land use policy. The ESA directly applies only to specific species, instead of landscape ecosystems and specific geographic areas that contain potential endangered species habitat.

The guidelines could be developed based on a review of existing planning support systems that are used by local governments. They should also be based on the findings from mock exercises that simulate impacts of urban growth scenarios on landscape ecological systems, as well as impacts on local fiscal conditions, transportation, and public facilities. Case studies could also be prepared that summarize community projects that have successfully incorporated landscape ecological information into planning support systems to address the impacts of alternative scenarios of land use change.

Land Use Classification Systems for Environmental Conservation

Open space and conservation land use classification systems need to be better coordinated for linking green spaces across local jurisdictions. In practice, most local planning agencies use land classification systems that respond to their particular needs, usually combining categories from their land use plans, zoning ordinances, and tax assessors' inventories. But jurisdictionally unique classification systems make it difficult to assemble regional land use data bases with consistent categories. This situation creates inconsistencies and potential conflicts in planning for and managing regional concerns like landscape conservation, but also in estimating the demands for transit, highways, and other public services (water, sewer, health care, etc.).

The aim must be to develop classification standards that maximize biodiversity and overall regional eco-

While planning support systems are an integral part of most local government planning programs, they rarely incorporate landscape ecological data.

Regionalism is also about limiting consumption of environmentally sensitive areas and open spaces on the urban fringe by channeling new growth toward the most suitable areas.

logical value (Kramer and Dorfman 2006). The highest-value landscapes would be targeted for protection and classified as not suitable for development. Successful examples of regional green space land classification systems for the Portland, Oregon Metro Region and the Research Triangle Region in North Carolina have been developed, but these cases are the exception rather than the norm. A key step forward would be to build on current land classification initiatives, most notably the LBCS of the American Planning Association (www.planning.org/lbcs/), and the National Resources Inventory (NRI) of land cover and use, soil erosion, prime farmland, wetlands, and other natural resource characteristics found on rural land in the United States (www.wi.nrcs.usda.gov/technical/nri/what.html). The next step would be to extend the LCBS and NRI to include more appropriate and refined classification standards that capture landscape ecological values.

What changes in land use planning practices and institutions could make communities more receptive to and able to implement science-based conservation recommendations?

Improved Regional Collaboration in Planning

Stronger regional planning would more effectively support the application of science-based, landscape-scale information to protect ecological systems. Regionalism is not just about consolidating little boxes to save money and limit duplicative municipal services. It is also about limiting consumption of environmentally sensitive areas and open spaces on the urban fringe by channeling new growth toward the most suitable areas. At the same time, fostering a stronger sense of regionalism helps support the achievement of other core regional goals, such as reduced automobile-dependence through public transit, and revitalized economies from directing growth into declining inner urban areas rather than the urban-rural fringe.

After decades of policy debate and academic research, regionalism is experiencing a rebirth, in the form of changing formal structures of government and in changing allocation of powers across government. The rebirth has been prompted, in part, by federal action. The federal government has begun to recognize that issues that span jurisdictional boundaries need cross-jurisdictional solutions and entities that bring together representatives of the entire region to seek solutions.

One example is the devolution of responsibility for species habitat protection from federal agencies to public and private entities at the regional level, through the creation of regional habitat conservation plans under the federal Endangered Species Act. While such plans date from the early 1980s, they have been used with much greater frequency since the mid-1990s. Another example is the federal government's devolution of responsibility for transportation and air quality decision-making to metropolitan entities through the federal transportation laws, commonly referred to as ISTEA and TEA-21 laws. Urban policy scholar Bruce Katz (2006) calls these types of federal activities "functional regionalism" because they alter the allocation of powers across different levels of government.

At the local level, American metropolitan areas are experimenting with new forms of formal and informal regionalism that offer opportunities for landscape conservation. One leading example of formal regionalism involves the City of Louisville and Jefferson County, Kentucky. In 2000, both local governments collaborated in adopting their Cornerstone 2020 Comprehensive Plan, which supports compact development, protects green spaces (wetlands, major forested areas, nature preserves, and stream corridors), and targets use of land acquisition funds to maximize landscape-scale natural values. The plan also provided a vision that served as a guide for officials and stakeholders during the city-county consolidation process in 2003. With the stroke of a pen, Louisville jumped from the 64th largest city in the U.S to the 16th. This consolidation also led to the adoption of a unified Land Development Code in 2003, which integrated environmental protection standards, streamlined development permitting for the private sector, and eliminated duplicative city and county services. An added benefit has been the corporate community's use of the consolidation in marketing Louisville as a green, livable, affordable, and efficient place to do business.

Other metropolitan regions have not gone as far as formal consolidation, but have set up informal mechanisms to enable regional collaboration. Chicago and Denver have active and successful councils of governments that convene to discuss and act on regional issues, with open-space protection as a core planning goal. These initiatives position regional reform not as an end in itself, but as a means to advance smart growth and address the ills of sprawl, notably loss of open space, while advancing regional prosperity. A common theme that runs through these initiatives is building networks of institutions that "think regionally" and act in a regional context. The aim is to grow linkages among stakeholder groups that operate across local jurisdictional boundaries – e.g., environmental groups concerned about loss of open space and air pollution, inner-city groups who may want better transit for access to jobs, and employers in suburban locations who may need employees. This requires regular convening, greater exchange of information, and the development of trust among key players. The goal is build regional coalitions that will work together to seek consensus and act collectively.

New Visions of Land Use and Community Design

Another way to counter the fragmented and localized decision-making that limits application of ecological concepts and data is to take an expanded view of land use planning through creative use of regional-scale land use and community design solutions. The concept of "compact urban form" has received considerable attention as a vision for regional planning and for coordinating individual community planning initiatives. It entails the formation of interconnected networks of mixed-use and high-density nodes of development, linked by transit corridors. Within this network, regional open spaces create a landscape-scale commons and ecological identity that serves to protect environmentally sensitive areas.

Compact urban form has been widely promoted under the rubric of new urbanism since the late 1980s as an alternative to sprawl (Calthorpe and Fulton 2001, Duany et al. 2000). In addition to the social and economic benefits of compact urban forms, new urbanists claim that these developments provide more opportunities to protect landscape ecological systems and biodiversity, reduce auto dependency, and decrease air pollution. New urbanism has drawn increasing attention from land use and environmental policymakers. Communities in ecologically sensitive regions — like the Lake Tahoe watershed of California, Chesapeake Bay of Maryland, and Neuse River Basin of North Carolina — must now adopt land use planning programs that reflect the high-density and mixed-use elements of new urbanism as part of comprehensive management strategies to achieve biodiversity conservation goals and reductions in nutrient inputs from stormwater runoff (Maryland Department of the Environment 1995, North Carolina Department of Environmental and Natural Resources 2002). To achieve smart growth goals, these communities must conduct joint visioning and cooperative region-wide environmental monitoring, as well as adopt coordinated plans and implementation practices.

Since the mid 1990s, ten states have adopted smart growth legislation that requires or encourages local governments to alter existing development practices dominated by low-density sprawl (American Planning Association 1999, Godschalk 2000). An increasing number of local governments are experimenting on their own with specific plans, policies, codes, and development standards that promote new urbanism (Eppli and Tu 1999). Many observers of these state and local initiatives agree that in addition to social and fiscal benefits, new urbanism in the form of smart growth offers a more environmentally compatible form of development than sprawl (for example, Berke et al. 2003, Burchell et al. 2002, Godschalk 2000, Duany and Talen 2002).

One shortcoming in the literature on new urbanism is the lack of attention to conservation concerns. New-urban development codes support the basic goals of community character, sense of place, and pedestrian movement (Calthorpe 1993, Duany Plater-Zyberk & Company 2001). The codes include detailed standards for building disposition, configuration and function, as well as parking, civic space, and streetscapes. However, published design standards for habitat shape, size, and corridor width (Duerksen et al. 1997, Kennedy et al. 2003), and watershed-based zoning and stream buffers (e.g., Center for Watershed Protection 1995, Schueler 1995) have not been acknowledged and used. Inattention to ecological

State efforts to mobilize local communities and increase their capacity to plan proactively for biodiversity conservation can be leveraged through provision of grants-in-aid and better availability of technical information.

design standards can lead to ecologically insensitive developments on a site-by-site basis, as well as scattered developments across the landscape that do little to promote regional biodiversity conservation.

To address these shortcomings, the TransectMap has recently been developed by new-urban planners and designers (Criterion 2005). This GIS mapping tool overlays multiple sources of environmental information with features of the built environment to determine the overall suitability of new-urban developments in a regional planning area. The analysis is conducted to delineate six transect zones that specify the degree to which an area is suitable for new-urban development. Two zones — natural areas and rural conservation — place severe restrictions on new-urban developments due to the presence of critical natural features. The remaining zones (core, center, general, suburban) are suitable for different intensities of new urbanism depending on the environmental sensitivity of the land, the capacity of street networks and transit routes to accommodate non-auto movement, and the accessibility and capacity of existing infrastructure to accommodate growth. Environmental standards (e.g., steepness of slopes and widths of stream buffers) and urban development standards (e.g., distance of walking destinations such as transit stops, schools and parks) vary according to zone.

The TransectMap was recently applied to guide recovery in the three counties and eleven municipalities that were devastated by the 2005 Hurricane Katrina disaster along the Mississippi Gulf Coast (Criterion 2005). The aim is to help planners, environmental professionals, and their communities map transect zones and set standards to support visioning and comprehensive planning to encourage avoidance of redevelopment in ecologically sensitive areas, notably floodplains, and achievement of neighborhood design objectives consistent with new urbanism.

State Action to Strengthen Intergovernmental Partnerships

States should incite communities to take a more proactive role in promoting land use policy that supports conservation. The influence of states in guiding land use and development cannot be overestimated. States exercise considerable authority in specifying the land use powers of local government for planning, regulation, taxation and spending; as well as designing the skeleton of regions through assignment of local annexation authority, local property tax sharing arrangements, public infrastructure and urban service area investments, and the disposition of funds for green space and park acquisitions. While states can circumvent local authority and directly regulate land use, state governments also make important choices about creating partnerships to promote local environmental conservation practices. These choices can be classified by identifying three types of partnerships between state and local governments in the research on state growth management (Berke 1998, Bollens 1992).

One choice is mobilization. It simply entails states providing financial incentives (e.g., grants or loans for land acquisition funds and infrastructure investments) and credible information bases that call attention to the problem and can be readily used by local planning programs (e.g., location of wildlife habitats, distribution of threatened species, stream water quality). State governments may play only a limited role in mobilizing local communities if municipalities are not already philosophically committed and technically capable of taking action. State efforts to mobilize local communities and increase their capacity to plan proactively for biodiversity conservation can be leveraged through provision of grants-in-aid and better availability of technical information. Unfortunately, as discussed earlier, communities often remain apathetic until faced with an ecological "train wreck."

A second choice involves state-mandated local planning and regulation, where state government is a general partner with local governments in advancing environmental conservation. The state establishes planning goals, policies, and standards for acceptable local planning and regulation. The failure to take local action can bring state sanctions. Communities in states with planning mandates are more likely to have strong environmental provisions in their local plans and regulations than are communities without planning mandates (Berke et al. 1996, Burby and May et al. 1997). The limitation of this choice, however, is that the strength of community action varies considerably among communities operating under mandates. Simply regulating local actors and threatening them with sanctions does not lead to automatic compliance, especially in the context of environmental conservation, where local governments are often reluctant partners.

A third choice entails establishment of voluntary collaborative partnerships in which state and local governments work together to undertake land use planning and management actions. The key to success in this approach is that partners must be willing and able to undertake and fulfill their assigned roles. Group processes of consensus and commitment building, rather than top-down approaches by experts, are a key factor in explaining successful local responses to state policies in these collaborative partnerships (Berke et al. 1997). On the negative side, heavy reliance on voluntary local participation may increase the potential that only some communities will take action consistent with state plans, as effectiveness depends on willingness and capability of local partners (Berke 1998).

In sum, evidence on the effects of state planning policy indicates the need to pursue a combination of types of shared governance choices (Berke 1998, Burby and May et al. 1997). Collaboration enhances commitment of local partners. Mobilization helps build the technical capacity of already committed communities (usually those facing ecological "train wrecks") to use conservation information and take advantage of incentives. State-mandated local planning and regulation has the advantage of producing stronger plans and implementation actions across all regulated communities (with both high and low commitment and capability) compared to communities not under state mandates. Thus, a combined strategy for states might include a local mandate that raises the bar for all communities, collaboration that builds local political commitment (particularly communities that might resist state mandates and be unwilling to act proactively to avoid a "train wreck"), and mobilization that enhances the technical capacity of communities to act.

Expanded Views in Planning Education

The concepts and technical methods of landscape ecology and conservation biology should be incorporated as a fundamental aspect of planning education. Despite the wide availability of science-based information on landscape ecology and conservation biology for land use planning (e.g., Perlman and Miller 2005, Appendix D: Data Sources), the information is not being integrated into planning education. The most recent Guide to Undergraduate and Graduate Education in Urban and Regional Planning (ACSP 2006) indicates that only a few planning faculty have expertise in landscape ecology and biodiversity conservation.

Landscape ecology and conservation biology represent new thinking to most planning educators. Since contemporary plans give only limited attention to natural resource protection, planning educators must develop curricula that train students to think more comprehensively in seeing the links between ecology and land use, and to become more technically proficient with concepts like island biogeography, edge effects, and population viability analysis. This shift in thinking is crucial, since planning students will increasingly find themselves to be in the best position to serve a central agenda-setting, organizing, and consensus-building role in regional ecosystem conservation efforts.

Another key reform in planning education should be to focus strong attention on decision-making in the planning process. Future planners must be skillful in achieving coordination and consensus among multiple interest groups who have a stake in biodiversity and ecological health. They must employ various negotiation and dispute resolution techniques that are essential in formulating the holistic plans and ordinances needed to achieve more balance and incorporate ecological concepts. This entails confronting the classic conflicts encountered by planners and their communities in attempts to advance natural resource protection (e.g., "jobs versus environment" and "environment versus equity"), and providing competing interest groups the right kinds of unbiased information (e.g., economic data on the benefits of conserving habitat versus not conserving habitat) that could help take some emotion out of the arguments.

The concepts and technical methods of landscape ecology and conservation biology should be incorporated as a fundamental aspect of planning education.

At the start of the twenty-first century, the field of land use planning is well positioned to reform conventional urban development practices that do not give sufficient attention to biodiversity and landscape conservation.

Conclusions

In this paper, I examined the prospects for long-range land use planning as a potentially effective solution to landscape ecological decline. Whenever possible, I have relied on results from systematic studies of the response of local planning programs to conservation needs. While this research has made distinctive contributions to our understanding of the links between landscape ecology and land use planning, my review should be treated with caution, since studies that examine the causes and consequences of local conservation efforts are still limited.

The paper identifies major barriers that prevent application of sound landscape ecological concepts to local land use planning programs. The most evident barrier is the limits of local government planning programs trying to incorporate landscape ecological concepts into traditional planning tools. Plans have weak fact bases and vague policy frameworks related to landscape ecological issues, and communities have low rates of adopting plan implementation practices that address conservation. Two key barriers prevent improvement of local programs. One is the land use management paradox, which entails weak commitment for proactive conservation planning, but support for action only after the onset of an ecological "train wreck." Another barrier is the spatial mismatch between the scale of local planning authority and the need for regional-scale landscape ecological management.

My recommendations for overcoming these obstacles involve changes in planning practice and education, and improvements in ways to communicate scientific information. The recommended changes to planning practice to encourage the support of ecological protection include:

- Construct and support regional networks among stakeholder groups and government agencies that operate across local boundaries;
- Promote an integrated strategy for states to facilitate better local planning; and
- Advance an expanded view of planning education to include the concepts and analytical methods of landscape ecology in the curricula of accredited graduate and undergraduate planning schools.

Recommendations for improved communication include:

- Develop indicators that can be used to raise public awareness about ecological conditions, and monitor and evaluate plans;
- Establish best-practice guidelines on how to integrate ecological information into conventional planning support systems that are used in day-to-day planning practice.
- Improve green (or open) space classification systems to help support collaborative land use planning across local boundaries; and

Finally, it is important to offer a recommendation to improve our understanding of the factors that will enable local governments to adopt and implement land use planning programs that advance landscape ecological protection:

- Support studies that explicitly hypothesize casual links to explain how and why ecological concepts are incorporated into land use planning. Priority should be given to research that emphasizes multiple-case research designs, with each case using the same methods and variables to ensure comparability. I have identified a range of factors that potentially influence local response, including the land use management paradox, state-regional-local partnerships, alternative land use and community designs, indicators for monitoring environmental conditions and evaluating plans, landscape classification, and planning support systems. Multi-case research designs are needed to test the independent effects of these factors on advancement of ecological protection.

In sum, at the start of the twenty-first century, the field of land use planning is well positioned to reform conventional urban development practices that do not give sufficient attention to biodiversity and landscape conservation. Landscape ecological concepts offer new thinking about how to guide the planning agenda for the new millennium. Indeed, the complexity of the task requires holistic and integrative thinking – a task that should be a feasible ideal for land use planners who play central roles as stewards of the public interest.

Literature Cited

American Planning Association. 1999. *Modernizing State Planning Statutes: The Growing Smart Working Papers*. Planning Advisory Service #480/481. Chicago: APA Planners Press.

Association of Collegiate Schools of Planning (ACSP). 2006. "Guide to Undergraduate and Graduate Education in Urban and Regional Planning." www.acsp.org/Guide/ACSP_Guide_2006.pdf (Accessed February 27, 2007.)

Beatley, T. 2000. Preserving biodiversity: Challenges for planners. *Journal of the American Planning Association*. 66 (1): 5-20.

Berke, P. and T. Beatley. 1992. *Planning for Earthquakes: Risk, Politics and Policy*. Baltimore: Johns Hopkins University Press.

Berke, P., D. Roenigk, E. Kaiser, and R. Burby. 1996. Enhancing plan quality: Evaluating the role of state planning mandate for natural hazard mitigation. *Journal of Environmental Planning and Management*. 39 (1): 79-96.

Berke, P., J. Dixon, and N. Ericksen. 1997. Coercive and cooperative intergovernmental mandates: A comparative analysis of Florida and New Zealand environmental plans. *Environment and Planning B*. 24: 451-68.

Berke, P. 1998. Reducing natural hazards risks through state growth management. *Journal of the American Planning Association*. 64 (1): 76-87.

Berke, P. and M. Manta-Conroy. 2000. Are we planning for sustainable development? An evaluation of 30 comprehensive plans. Journal of the American Planning Association. 66 (1): 21-33.

Berke, P., J. McDonald, N. White, M. Holmes, K. Oury, and R. Ryznar. 2003. Greening development for watershed protection: Does new urbanism make a difference? *Journal of the American Planning Association*. 69 (4): 397-413.

Berke, P., D. Godschalk, and E. Kaiser with D. Rodriguez. 2006. Urban Land Use Planning, 5th Edition. Chicago: University of Illinois Press.

Berube, A., B. Katz, and R. Land (eds.). 2005. *Redefining Urban & Suburban America: Evidence from Census 2000*. Washington, D.C.: Brookings Institution Press.

Bollens, S. 1992. State growth management: Intergovernmental frameworks and policy objectives. *Journal of the American Planning Association*. 58 (4): 454-67.

Brody, S. 2003a. Examining the effects of biodiversity on the ability of local plans to manage ecological systems. *Journal of Environmental Planning and Management*. 46 (6): 817-37.

Brody, S., W. Highfield, and V. Carrasco. 2003b. Measuring the collective planning capabilities of local jurisdictions to manage ecological systems in southern Florida. *Landscape and Urban Planning*. 69: 33-50.

Brody, S., W. Highfield, H. Ryu, and L. Spanel-Weber. 2006. Examining the Relationship between Wetland Alteration and Watershed Flooding in Texas and Florida. College Station, TX: Environmental Planning & Sustainability Research Unit, Hazard Reduction and Recovery Center, Texas A&M University.

Burby, R. and S. French. 1981. Coping with floods: The land use management paradox. *Journal of the American Planning Association*. 47 (3): 289-300.

Burby, R., S. French, B. Cigler, E. Kaiser, D. Moreau, and B. Stiftel. 1985. *Floodplain Land Use Management: A National Assessment*. Boulder, CO: Westview Press.

Burby, R., and P. May with P. Berke, L. Dalton, S. French, and E. Kasier. 1997. *Making Government Plan: State Experiments in Managing Land Use*. Baltimore: Johns Hopkins University Press.

Burchell, R., G. Lowenstein, W. Dolphin, C. Galley, A. Downs, S. Seskin, K. Still, and T. Moore. 2002. *Costs of Sprawl – 2000*. Washington, DC: National Academy Press.

Calthorpe, P. 1993. *The Next American Metropolis: Ecology, Community, and the American Dream*. New York: Princeton Architectural Press.

Calthorpe, P. and W. Fulton. 2001. *The Regional City*. Washington, DC: Island Press.

Center for Watershed Protection. 1995. *Site Planning for Urban Stream Protection*. Ellicott City, MD: Author.

Coburn, J. 2004. Confronting the challenges of reconnecting urban planning and public health, *American Journal of Public Health*. 94 (4): 541-46.

Criterion. 2005. *TransectMap: A Transect Calibration & Delineation Method*. Portland, OR: Criterion Planners. www.crit.com (Accessed February 27, 2007.)

Daniels, T. 1999. *When City and Country Collide: Managing Growth in the Metropolitan Fringe*. Washington, D.C. Island Press.

Duany, A., E. Plater-Zyberke, and J. Speck. 2000. *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream*. New York: North Point Press.

Duany Plater-Zyberk & Company. 2001. *SmartCode*. Miami: Author.

Decker, D. 2001. *GIS Data Sources*. New York: John Wiley and Sons.

Duany, A. and E. Talen. 2002. Transect planning. *Journal of the American Planning Association*. 68 (3): 245-66.

Duerksen, C. J., D.L. Elliott, N.T. Hobbs, E. Johnson, and J.R. Miller. 1997. *Habitat Protection Planning: Where the Wild Things Are*. Planning Advisory Service Report No. 470/471, 82pp.

Eppli, M. and C. Tu, 1999. *Valuing the New Urbanism: The Impact of the New Urbanism on Prices of Single-family Homes*. Washington, D.C.: Urban Land Institute.

Godschalk, D., D. Brower and T. Beatley. 1989. *Catastrophic Coastal Storms: Hazard Mitigation and Development Management*. Durham, NC: Duke University Press.

Godschalk, D. 2000. Smart growth around the nation. *Popular Government*. 66(1): 12-20.

Katz, B. 2006. *Transforming Metropolitan Governance in Syracuse: A Roadmap for Prosperity*. Washington, D.C.: The Brookings Institution.

Kaiser, E., D. Godschalk, and S. Chapin. 1995. *Urban Land Use Planning-4th Edition*. Chicago: University of Illinois Press.

Kaiser, E. and J. Davies. 1999. What a good plan should contain: A proposed model. *Carolina Planning*. 24 (2): 29-41.

Kennedy, C., J. Wilkinson, and J. Balch. 2003. *Conservation Thresholds for Land Use Planners*. Washington D.C.: Environmental Law Institute.

Kent, T.J. 1990. *The Urban General Plan*. Chicago: American Planning Association Press.

Klosterman, R. 2001. The what if planning support system. In *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools*. Richard Brail and Richard Klosterman, eds.: 285-308, Redlands, CA: ESRI Press.

Kramer, L. and J. Dorfman. 2006. *A Toolkit for the Evaluation of Land Parcels for Greenspace Planning*. Athens, Georgia: Institute of Ecology, University of Georgia. http://www.rivercenter.uga.edu/publications/pdf/toolkit.pdf (Accessed February 27, 2007.)

Maryland Department for the Environment. 1995. Maryland's Tributary Strategies for Nutrient Reduction: A Statewide Summary. Annapolis, MD: Author.

McElfish, J. 2004. *Nature Friendly Ordinances*. Washington, D.C.: Environmental Law institute.

Norton, R.K. 2005. More and better planning: State-mandated local planning in coastal North Carolina. *Journal of the American Planning Association*. 71(1): 55-71.

North Carolina Department of Environmental and Natural Resources. 2002. Neuse River Basinwide Water Quality Plan. Raleigh, North Carolina: Author.

Orfield, M. 1997. *Metropolitics: A Regional Agenda for Community and Stability*. Washington, D.C.: Brookings Institution Press.

Perlman, D. and J. Miller. 2005. *Practical Ecology for Planners, Developers, and Citizens*. Washington, D.C.: Island Press.

Reinhold, R. 1993, March 16. Tiny Songbird Poses Big Test of U.S. Environmental Policy. *New York Times*, p. A1.

Seasons, M. 2003. Monitoring and evaluation in municipal planning: Consideration of realities. *Journal of the American Planning Association*. 69 (4): 430-40.

Schueler, T. 1995. *Environmental Land Planning Series: Site Planning for Urban Stream Protection*. Center for watershed Protection, Pub #95708, 232 pp.

Beyond This Point, There Be Dragons
Charting the Waters of Natural-Resource-Based Land Use Planning in Pima County, Arizona

Arlan M. Colton, FAICP and Sherry A. Ruther, Pima County, Tucson, Arizona.

Introduction

Understanding some of the history of Pima County's development and its growing pains will afford insight into our responses to the questions presented and discussed in following sections, and provide a needed context for the evolution and application of natural-resource-based land use planning as a whole. Although this essay focuses on unincorporated Pima County, the reader should be aware that incorporated cities and towns that exist within Pima County do maintain separate and independent land use regulatory authority. In order for us to achieve a single, coordinated regional approach to land use planning that incorporates natural-resource conservation considerations, we will necessarily have to address jurisdictional independence.

We hope to raise relevant issues and insights that will be transferable from community to community. However, it is unlikely that the roadmap used by one community can be successfully used in another community without modification. There is no one-size-fits-all equation to cultivating a resource conservation ethic in a community's approach to land use planning.

The degree to which any given community is successful in establishing natural-resource conservation as a touchstone for its approach to land use planning is greatly dependent on several factors: the ripeness of conservation as a community issue; the quality, scope, and availability of resource-based information; the presence of far-sighted resource experts, political leaders, and key members of the public who are willing to take calculated risks; the existence of entities who can serve as translators between the disciplines of land use planning and natural-resource conservation; and, not surprisingly, financial wherewithal. From our perspective, these elements are essential to success, but the ability to orchestrate their genesis and timing varies from community to community.

Pima County - The Planning Context.

Pima County is physically about the size of the state of New Jersey (Figure 1). By most accounts the County's population has hit the 1,000,000 mark in November 2006, making it the second-largest by population in Arizona. Its county seat, Tucson, is one of the oldest Arizona cities. The city was the largest in

FIGURE 1

the state in the early part of the 20th century, but despite steady growth, it has been the second-largest city behind younger Phoenix for years. This is likely to change, as both the Phoenix metro area (Maricopa County) and Pinal County (the county geographically between Maricopa and Pima) continue to grow at a very rapid pace.

The vast majority of the County's growth has taken place in its unincorporated eastern portion. Over a third of the population of Pima County now lives in these unincorporated lands around Tucson (Table 1). Because of this growth pattern, Pima County plays a significant role in the development of the region (Figure 2).

The Tucson region largely has been defined by the vast public preserves that surround it: to the north, east, and south, a major national forest; to the east and west, a large national park; to the west, a very large county park. In the late 1960's and early 1970's, the national environmental movement took hold here. For a brief time in the mid-1970's and into the early 1980's, local elections were often dominated by a debate about how growth should proceed. The pro-

TABLE 1. Size statistics for the five incorporated jurisdictions in eastern Pima County (Pima Association of Governments 2005). All the incorporated communities have the ability to annex except the City of South Tucson, which is surrounded by the City of Tucson.

Community	Population (estimate 2005)	Square miles (approx 2005)
Tucson	529,770	226.8
Marana	26,725	118.1
Oro Valley	39,400	34.7
Sahuarita	13,990	30.4
South Tucson	5,630	1
Unincorporated area	342,120	8789
Totals	957,635	9200

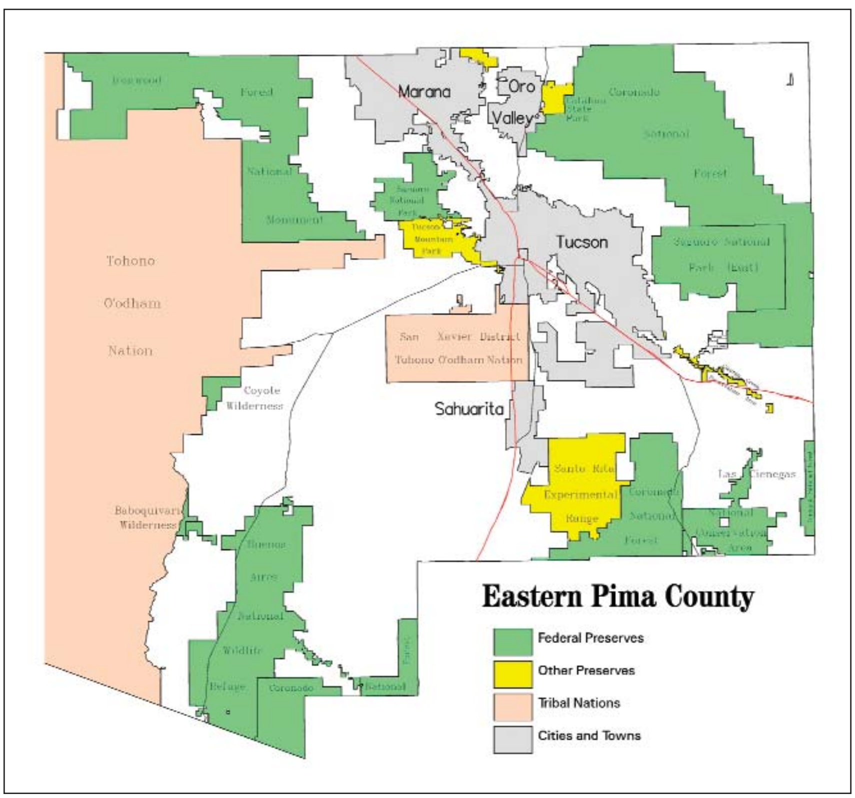

FIGURE 2

growth, no-growth, and controlled growth debates were largely concerned with issues of land, water, preservation of desert vistas, and transportation modes. The divisions were not so much characterized by political party as by how each participant made his or her living, and how growth was perceived to contribute to individual economies. With the saguaro cactus as a major symbol, few argued, at least publicly, for obliteration of the desert as the community grew outward. The concepts of biodiversity protection and multi-species wildlife habitat planning came later.

As development moved forward, opposition to a large number of projects turned on preserving the desert, or some aspect of it. Although most projects in this time period were approved, quite a number of them were never built because of their speculative nature. For those projects that did materialize, environmental commitments were frequently informal agreements and did not come to fruition. Consequently, conservation-related considerations received a lot of airtime, but did not get addressed on the ground with any consistency.

In the 1970's the County adopted eight sub-area plans in major growth areas that were developed, at least in part, through the analysis techniques described in the landmark 1969 work by Ian McHarg, *Design with Nature*. Despite the fact that these sub-area plans and their vision for the evolution of land use were formally adopted, amendments to these plans were relatively easy to obtain. In fact, many amendments were approved at the same time as rezoning of property. Most of these sub-area plans along with an overall general land use plan that dated from 1960 were replaced in 1992, with the adoption of a new County comprehensive plan.

After adoption of the Arizona "Growing Smarter" Acts of 1998 and 2000, an updated Comprehensive Plan was adopted in 2001. Recognizing a convergent opportunity to comply with the environmental requirements of the Growing Smarter Act of 2000 and to address endangered species issues related to the cactus ferruginous pygmy-owl, Pima County initiated the Sonoran Desert Conservation Plan, and incorporated it as a major underpinning of the 2001 Comprehensive Plan Update. (The Sonoran Desert Conservation Plan is discussed in more detail in subsequent sections.) As required by Growing Smarter and reinforced by Pima County ordinance, all rezoning requests must now conform to the Comprehensive Plan, which includes area-specific conservation objectives. If the requested zone is not compatible with the comprehensive plan, the comprehensive plan must, through a separate process, be successfully amended prior to requesting the rezoning.

In addition to planning processes and the zoning code's regulatory framework, beginning in the mid-1980's, the County adopted new procedures for processing land use changes. Since the early 1950's, urban areas had been zoned primarily to reflect those land uses that existed or would be generally compatible with existing land uses. Outlying rural and suburban areas, where virtually all development occurs today, were typically zoned for residential uses at intensities of one residence per acre or one residence per 3.3 acres (the least intensive residential zoning designation available at that time). In 1985, concerns over rampant lot splitting (subdividing without a plat allowed by Arizona law) and its associated adverse environmental impacts led to a major downzoning of rural Pima County to limit residential uses to one residence per 4.13 acres. This downzoning was not accomplished without huge controversy; at one public meeting, planners were met with tar and feathers, at least symbolically.

Pima County – The Conservation Ethic.

The beginning of Pima County's long-standing conservation ethic came in 1929 with the establishment of Tucson Mountain Park, which at that time included what is now the West Unit of Saguaro National Park. Its founding was grounded in an interest to protect the unique landscape and resources of the Tucson Mountains. Today, our conservation ethic, buttressed by the need to protect the public health, safety, and welfare, manifests itself in the County Zoning Code and in adopted development policy.

Traditionally, environmental concerns about the effects of proposed land use changes were addressed, more often than not, as a reaction to perceptions – perceptions about a development's potential (1) to adversely impact the landscape or a specific biological resource, or (2) to generate undesirable impacts to the community and neighborhood lifestyle.

Arguably the first case of a more proactive, *a priori* code-based environmental protection was the adoption of a hillside development overlay zone in 1976. Today, Pima County's Zoning Code includes overlay zones or chapters that protect native plants, seek to buffer public preserves, provide for low-water use landscaping, limit golf course turf, and regulate the amount and location of grading. The protection of floodway and floodplain areas, as well as the riparian resources associated with these areas, is accomplished through the regulatory authority of the regional flood control district.

After years of regulating based on individual landforms (slopes) and areas (public preserve buffers), Pima County in the mid-1980's began to migrate toward a more habitat- and resource-based approach. This had its early beginnings in the identification and mapping of high-value vegetation communities (e.g., saguaro-ironwood communities and riparian corridors) in the Tucson basin (Shaw et al. 1986).

As part of this shift toward a habitat- and resource-based approach, the County adopted a requirement for a McHarg-inspired site analysis to accompany rezoning applications. The site analysis requires disclosure of the availability of infrastructure to the proposed project and on-site natural resource features, which early on included those sensitive vegetation communities identified by Shaw et al. Accompanying documentation must also include a preliminary development plan showing how a proposed development responds to these site opportunities and constraints. Each approved rezoning is contingent on substantial conformance with the preliminary development plan at the time of subdivision and development.

Site-analysis requirements, especially those pertaining to habitat and natural resources, have been strengthened over the years, and now require applicants to disclose information about the development's relationship to high-profile natural resources identified by the Sonoran Desert Conservation Plan. This concept of disclosing a site's natural resource- and infrastructure-related characteristics is now used in one form or another by each of the jurisdictions in the County, and in a number of other areas around the state. The tool is successfully used by the County and the private sector as a site-planning tool, but can-

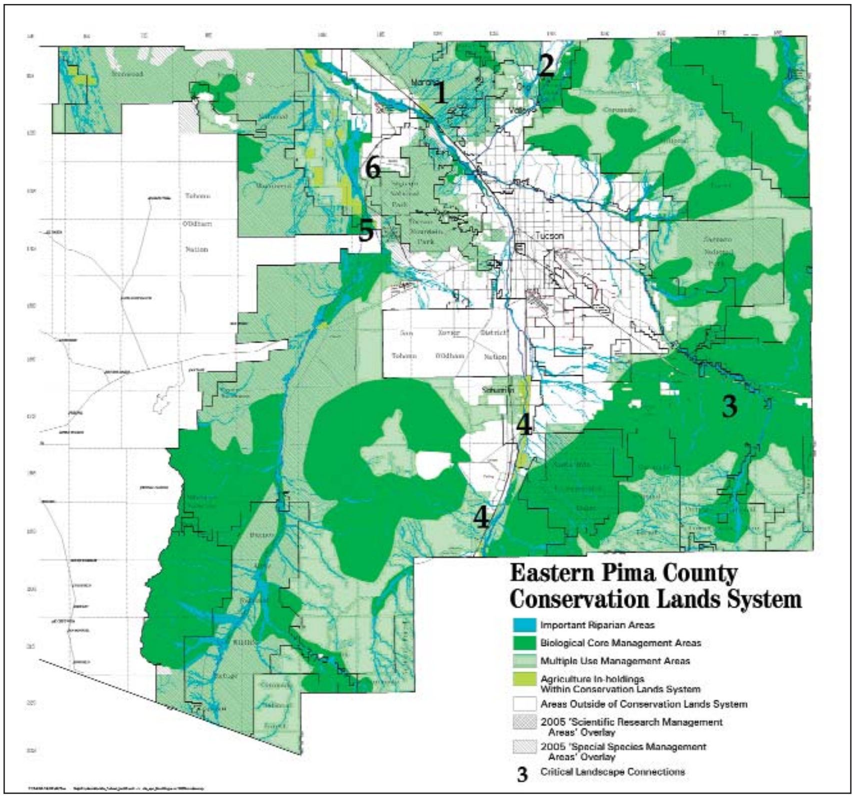

FIGURE 3

not substitute for long-range land use and conservation planning on a regional basis. It should be viewed, however, as a complementary tool that serves to refine regionally-based, landscape-scale resource information for application on a project-specific scale.

Pima County – The Sonoran Desert Conservation Plan.

The genesis of the Sonoran Desert Conservation Plan (SDCP) lies in the 1996 listing of the cactus ferruginous pygmy owl as a federal endangered species under the Endangered Species Act. For the first time in Pima County's history, a federally endangered species collided with development patterns. However, the scope and breadth of the SDCP quickly expanded beyond the realm of dealing with one endangered species, and evolved into a more comprehensive, long-term vision for balancing the community's economic vitality with the protection of its cultural and natural heritage. This vision required a level of understanding about the resource values of lands in Pima County, as well as their geographic distribution across the landscape, that did not exist at the outset. After several years and the investment of significant dollars, this science-based data emerged in the form of the Conservation Lands System (Figure 3).

The Conservation Lands System is our road map to conserving biodiversity. At a landscape scale, it delineates the juxtaposition between areas desirable for urban development and areas necessary to maintain Pima County's biological richness. Built from the expertise of more than 100 local and regional biologists, ecologists, and natural-resource specialists, the Conservation Lands System applies current principles of ecological reserve design, and synthesizes species-specific habitat models and vegetation community inventories. The end result is a classification of lands based on their relative value to biodiversity. Conservation objectives for each classification category were also developed and are expressed largely in terms of the retention of undisturbed natural open space. For example, the conservation objective for Biological Core Management Areas is to retain 80 percent of lands with this designation as undisturbed natural open space. Multiple Use Management Areas, with a target of 66? percent undisturbed, natural open space, have the lowest conservation objective.

While most conservation objectives are expressed quantitatively, some are purely qualitative. Critical Landscape Connections, for example, are those areas where movement of native biological resources still exists but is significantly constrained, and where movement of native fauna and pollination of native flora across the landscape should be maintained and enhanced when possible.

In addition to other tools, such as land acquisition[1], that the County is applying to achieve the goals of the Sonoran Desert Conservation Plan, the Conservation Lands System was incorporated as a significant element of land use planning. The Conservation Lands System map and its associated conservation objec-

1. In 2004, voters in Pima County approved a Conservation Bond Program that earmarks $174 million for the sole purpose of acquiring open space. As of January 2007, Pima County has spent $74 million to secure 25,500 acres in fee simple.

tives were folded into the 2001 Comprehensive Plan Update as part of the Environmental Element - Regional Plan Policies, which resulted in the application of conservation set-aside objectives to specific types of development proposals (i.e., comprehensive plan amendments and rezoning requests). Elevating the Conservation Lands System and the application of conservation set-asides to the status of a regional comprehensive plan policy has taken consideration of natural resource conservation to an unprecedented level in the County's land use planning history. Much more has been written elsewhere on the history and evolution of the Sonoran Desert Conservation Plan and the Conservation Lands System, most notably in *Nature Friendly Communities* (Duerksen and Snyder 2005).

Given our local experiences in incorporating science-based conservation into land use planning we were asked to address several specific questions.

What are the major barriers to applying ecological science-based information to land use planning?

Political and legal realities.

No surprise here: these two barriers are perpetually at the top of the list for anyone who is wrestling with matters of governance that entail balancing public health, welfare, and safety with private property rights. There are two significant ways in which political and legal realities constrain the use of land use planning as a mechanism for accomplishing resource conservation. First, they establish and define the limits of creative applications. For example, the ability of Arizona counties to employ the transfer of development rights as a tool to shift development pressure away from lands with high biological values was only a fantasy until 2005, when the state legislature granted them the specific authority to utilize this tool. As entities of the State, Arizona counties are, for better or worse, only able to engage in those powers that are affirmed by the State.

Second, political and legal realities often foster a decision-making context that subjects land use proposals that are predicated on solid resource information and sound planning principles to the preferences and opinions of the public and elected officials, whose decisions often reflect other priorities. It is not uncommon for land use decisions to represent neighborhood desires and/or constituent priorities over the pure application of planning principles or resource-conservation objectives.

Rarity of Hybrids.

There is a plethora of evidence — everything from peer-reviewed research to articles in professional publications to joint symposia — that land use planners and natural resource professionals have cross-pollinated each other's professions. However, true hybrids are rare. Those folks who can competently function in both professions will be key players as we transition into the next level of conservation-based land use planning. The ability to incorporate natural-resource-based information into the various levels of land use planning, in a manner that maintains the integrity and effectiveness of that information, is essential. In the majority of instances, the scale at which most resource-based information is collected is not directly comparable to the scale at which land use planning seeks to apply such information. For example, extrapolating pertinent kernels of information from research performed on a scale of square miles in order to apply it on a parcel-by-parcel scale is challenging enough for resource experts; to expect planners to do so without possessing a comparable level of resource expertise is misguided, at best, and has potentially deleterious consequences.

There is also the matter of credibility. Land use planners, on more occasions than they'd care to admit, find themselves in the uncomfortable position of having to defend or revise expert natural-resource-related recommendations on the fly. Absent the appropriate natural-resource pedigree, any response from the planner, regardless of its accuracy, is often viewed as suspect.

Substitution of aesthetic values for conservation values.

It is our experience that land use planning commonly focuses on conserving resources that have a significant amount of aesthetic appeal, regardless of the conservation values that are at stake. While there is no question that some resources are more aesthetically appealing than others (Sonoran Desert examples include lush riparian areas, stately saguaro cacti, cute little pygmy-owls, etc.), there is a tendency to

However, true hybrids are rare. Those folks who can competently function in both professions will be key players as we transition into the next level of conservation-based land use planning.

While the biologist speaks the language of wildlife habitat and landscape linkages, and the planner speaks of a sense of place and mixed-use development, many people tend to think and speak in terms of visual aesthetics or property values.

substitute the public's aesthetic values for pure conservation values. Consequently, land use planning practices influenced by this type of bias often result in disproportionate development of unattractive resources; provide few-to-no mitigation standards or conservation strategies for these less appealing resources; and unintentionally promote the loss of biodiversity. Unfortunately, the on-the-ground effect of such practices conflicts with the fundamental ecological principle that all ecosystem components are unique, yet inter-related, elements that are vital to sustaining biodiversity and healthy ecosystems. Explaining this to the public, decision-makers, and especially the landowner is challenging.

Case in Point: In Pima County, riparian communities such as mesquite bosques and cottonwood-willow gallery forests as well as saguaro – palo verde – ironwood communities are structurally diverse, densely vegetated, visually appealing vegetation associations. Creosote flats, on the other hand, have a less complex vegetative structural diversity, and present a more open, sparsely vegetated vista. Most observers would agree that the visual and aesthetic impact of creosote flats is less than appealing. Yet, when examined for their conservation values, creosote flats provide unique habitats and an array of species that are not found in other places. However, even in the face of Pima County's environmental sensitivity and forward-thinking Sonoran Desert Conservation Plan, creosote flats have been subject to decisions and policies that are arguably still influenced by aesthetic bias. This subtle bias needs to be exposed and reckoned with in a more conscientious manner.

What types of science-based information and technology would be most useful in supporting application of land use conservation tools to land use planning and ordinance drafting?

What is not there.

Just as a coin has two sides and every (pre-digital) photograph has a negative, conservation-oriented land use planning needs to be able to take advantage of resource-based information that describes both what does and does not occur along the land use spectrum. The current balance of resource-based information is more heavily weighted with descriptions of what the researcher finds, versus what they don't find: mortality rates of saguaro cacti within a golf course setting; habitat utilization of deer in an urbanizing area; number of raptor nest sites by land use. While it is incontrovertible that such studies have and continue to make essential contributions to our collective understanding of the biological resources that occur within urban and urbanizing environments, it is just as important to understand at what place along the land use gradient individual biological resources cease to occur – and why.

Such information about where and why certain resources cease to persist can improve the conservation effectiveness of land planning and ordinance drafting. With an improved ability to understand what resources are likely to persist or be lost, land planners and biologists can more fully anticipate the broader consequences of changing land uses in certain areas, especially those at the urban-exurban interface and other locations where critical resources are found. Specifically, a more intimate understanding of the causal relationship between a threshold land use and the absence of certain resources – assuming that the causal relationship is related to something that is subject to land use regulation – could provide the level of detail and focus that is necessary for drafting an ordinance. Ordinances written in this vein could promote or control certain activities that are shown to affect the persistence or absence of target resource elements.

Indirect impacts.

While our awareness of the direct impacts of land use activities (e.g., loss of natural lands, mortality, vegetation loss, drying of natural water sources, etc.) on natural resources has increased, we have only just begun to address the less obvious effects. Artificial night lighting, genetic isolation, temperature modification, and chemical interactions are just a few of the more elusive topics whose full ramifications are yet to be determined and considered in land use planning. The potential for information on these impacts to be incorporated into conservation-oriented land use planning is great. Once the sources of indirect effects and associated consequences are better understood, land use planning practices can be evaluated and designed to better mitigate undesirable impacts. For example, establishing requirements that consider lighting placement and emissions for those land uses in proximity to natural areas could minimize disruption of ecological functions such as migration, predator-prey relationships, and reproduction. We still have miles to go to gain a better understanding of how these less direct impacts extend their sphere of influence outward from developed areas through the landscape, and how these impacts can be addressed through land use planning practices.

Comparative conservation values.

Pima County is in as much need of the previously mentioned types of data as any other community; however, the question of what land use intensities and associated configurations of natural open space provide the best opportunity to retain conservation values is among the most pressing. Currently, most of those lands within Pima County that are more remote from the urban core are hard-zoned at a designation that, at minimum, allows for one residence per 4.13 acres. Planners and natural resource conservation professionals need a better understanding of how the conservation values of lands in areas designated for low density compare to those lands that are developed at higher densities, but that set aside up to 80% of the property for conservation. There are competing arguments, but definitive data is not available. In Pima County, both of these scenarios currently receive equal weight in attaining conservation objectives, but is this the correct strategy?

What changes in land use planning practices and institutions could make communities more receptive to and able to implement science-based conservation recommendations?

Make it personally and politically relevant.

Leaders have to find ways to bridge the perceived chasm between conservation of the environment and economic vitality of the community. Morris K. Udall, the legendary statesman who for years represented Pima County in the U.S. Congress, figured this out as he championed environmental causes here and throughout the country.

Support for conservation is easier when economic times are good; when they are less stellar, conservation can often be perceived by the populace as a luxury well down on the list from food and shelter. Pima County is by and large not a rich community. The cost of housing, for example, has escalated in recent years, and has become unaffordable to many. It is commonly believed that, like many other areas of Arizona outside the huge economic engine of metropolitan Phoenix, people live here and move here because of attraction to place, not because it is likely to make them rich.

Because most residents appear to like this place for an individual combination of visual, climatic, cultural or familial reasons, if their human survival needs can be met and if they are not highly inconvenienced or overly taxed, the bias toward conservation shines through. Finding the balance between championing a robust economy and a robust place is important.

While the biologist speaks the language of wildlife habitat and landscape linkages, and the planner speaks of a sense of place and mixed-use development, many people tend to think and speak in terms of visual aesthetics or property values. The role of the two professions may be, first, to understand each other's perspectives and meld their language toward achieving common goals. Second, they must be able to communicate together with the public, taking into account the public's values, thereby ensuring that all perspectives are addressed to the greatest extent possible.

Public participation is key. The public needs to buy in to, to recommend, and to see results that reflect their values. Solutions cannot be forced on people, for they will surely either fail or create enmity that can last for years. It is critical that we adopt public participation techniques that go beyond the perfunctory neighborhood meeting or the public hearing held immediately prior to a decision made by an elected or appointed body. Furthermore, data must be made available to the public and the process must be reasonably transparent. For the computer literate, the internet is our best friend, but planners and biologists must always remember that low tech is still necessary, and for many, more easily grasped. Never underestimate the power of one-on-one conversation.

It is critical that we adopt public participation techniques that go beyond the perfunctory neighborhood meeting or the public hearing held immediately prior to a decision made by an elected or appointed body.

We should be challenging ourselves to construct implementation strategies that … touch multiple sectors of the community, forge complementary and synergistic relationships between individual applications of tools in the toolbox, and create certainty for the community.

Build a diverse, integrated toolbox.

If one considers natural-resource conservation as an investment, then we must heed the savvy investor's mantra of "diversify, diversify, diversify". Achieving resource conservation through the application of a single tool, or even several tools individually applied, is passé. We should be challenging ourselves to construct implementation strategies that multi-task. At a minimum, strategies should touch multiple sectors of the community, forge complementary and synergistic relationships between the individual applications of tools in the toolbox, and create certainty for the community.

For example, regulating private development in conjunction with conservation-based standards for public-capital improvement projects and voter-approved bond packages to acquire biologically important areas collectively engage a cross-section of any community – private, public, individual. The next step comes in orchestrating the individual outcomes of these strategies in a manner that supports a whole that is greater than the sum of its parts. This does assume, of course, that a picture of the "whole" has been articulated (e.g., healthy riparian areas, retention of biodiversity, landscape connectivity, viable habitat for *X* species). In some minds, creating greater certainty for the community underlies the success of the other strategies we have mentioned.

While Pima County continues to add to and modify its land use regulatory framework in multiple ways to fit the nature of changing times and community needs, there is a limit beyond which innovation becomes stymied as we reach for the lowest common denominator of community development. Beyond this point, planners must think more creatively toward developing incentives for conservation, for community design, and for the integration of the two. What incentives will a community be willing to give – density, height, fee reduction, subdivision processing time – particularly in communities for which the use of incentives is quite foreign? Pima County is just beginning this conversation, but it is one that needs to be joined.

Regulation is one tool, but it is not *the* only tool. By design, land use regulation is applicable to certain defined actions. Due to the scope of conservation needs, other farther-reaching tools must be available. The toolbox must contain the capability and funding to purchase the highest-value conservation lands, or at least some or all of the development rights thereto, and the choice of lands to acquire must make sense to the public. However, in almost any community or county in the western United States, striking the balance between taking more private land off the tax rolls and conserving open space for biological resources or any other reason is a discussion to which each community will have a localized response.

Don't neglect the built environment and social fabric of the communities.

In order to be sustainable, communities must flourish economically, socially, and environmentally. Achieving an effective balance between these three essential components is the key to maintaining a sustainable community. Pima County has done a pretty fair job in recent years in planning and implementing strong conservation policy. But with notable exceptions, the county's built environment is relatively undistinguished from the perspectives of innovation, smart growth and creative design. A strong focus on conservation can easily neglect the needs of the people who live and work here, and how they interact with the land that is conserved. What is the impact on one's commute or the cost of extending utility lines or the size of a mortgage or the distance between home and a gallon of milk? How does the conserved land separate or create communities and neighborhoods? What do those neighborhoods look like and how do their residents and businesses function in them? It may be too much to ask a burgeoning community or county to address these three essential components of sustainability equally well in the same time frame, but the need to find a balance that works for the long-term viability of the community is ever present.

Conclusions

Pima County remains a jurisdiction challenged by growth and its ability to plan, regulate, and create incentives for quality development in a balanced manner. We continue to struggle to protect the natural environment and meet the needs of a growing population that is faced with increasing costs of day-to-day living, especially housing. There is no positive resolution to certain problems, like Pima County's lack of state authority to control lot-splitting outside the subdivision process.

A community debate on smart-growth principles of density and good urban design is on the horizon. The view that low-density development is compatible with environmental goals must be evaluated in light of knowing that too much low-density zoning contributes to sprawl, transportation and air quality problems, the cost of infrastructure, and forces people to "drive till you qualify" or face being priced out of the housing market entirely. Density and mixed-use development, historically seen as the enemy of the modern Southwestern auto-oriented lifestyle, will need to be addressed. Otherwise, perpetual low density will expand further and further into areas that the Sonoran Desert Conservation Plan and the public have said they want to protect. Finally, the delicate balance between the need to develop, physically and economically, with the desire to protect landscapes, habitat, or the water supply is ever on edge. The pendulum has swung back and forth between development interests and resource protection more than once in Pima County. The swing was often tied to the community's current economic well-being.

The ethos of land use planning and responsible natural-resource conservation will persist as we continue on this journey. In reality, both fields have their art and science, but both also are influenced by politics and uncertainty. Speaking to fellow planners, we will continue to seek public consensus and always try to do the right thing. In accordance with the American Institute of Certified Planners Code of Ethics, planners represent either their client or employer, and have a primary obligation to the public interest. The application of pure science therefore is an input but not always the outcome, as planners work to come up with or elicit the best solutions. Likewise, natural-resource professionals will continue to improve our understanding of the environment. For those biologists who choose to translate and incorporate evolving scientific understanding into land use planning, they too will struggle with how best to do the right thing for their client base – plants and animals and the ecosystems that support them. Our journey together will be marked with adaptive creativity, as we will never be able to predict what dragons will confront us along the way.

Postscript

In November of 2006, Arizona voters adopted Proposition 207, the Private Property Rights Protection Act. A similar initiative appeared on the ballots of many other western states, but failed. While primarily focused on fighting the use of eminent domain for economic development purposes, the more draconian impact on state and local government is the section on "diminution of value." This concept would require that, from the date of enactment of the legislation and with certain notable exceptions, individuals could file claims seeking to have government actions regulating land use overturned or compensated for if they believe that the action diminished their property values. The burden of proof is on the governmental entity. Assuming the act is upheld, options to resolve a valid claim would be to (1) completely repeal the governmental action, (2) provide the claimant with cash compensation, or (3) grant the claimant with a property-specific exception to the action.

Assuming it survives likely appeals through the court system, the Act will have a significant impact on planning and zoning processes throughout Arizona, as was intended. While laws on the books at the time of the election are not affected, all Arizona jurisdictions are now analyzing what they may or may not do to update or modify existing rules or to adopt new ones that address the new legislation. Given that planning and zoning are considered dynamic processes that change with changing needs, the passage of Proposition 207 will be a challenge not only to future conservation efforts, but to community building overall. Stay tuned.

Literature Cited

Duerksen, C. J. and C. Snyder 2005. *Nature-Friendly Communities: Habitat Protection and Land Use*. Washington D.C.: Island Press.

McHarg, I. 1969. *Design with Nature*. Garden City, NY: Natural History Press.

Pima Association of Governments. 2005. Personal communication, Karen Lamberton, Pima Association of Governments, November 10, 2006.

Shaw, W.W., J.M. Burns, and K. Stenburg. 1986. *Wildlife Habitats in Tucson: A Strategy for Conservation*. School of Renewable Natural Resources, University of Arizona.

The delicate balance between the need to develop, physically and economically, with the desire to protect landscapes, habitat, or the water supply is ever on edge.

Good Politics Before Good Science? The Path to Successful Public Conservation Planning

Timothy P. Duane, University of California, Berkeley

Efforts to incorporate "science" into conservation planning processes must therefore directly address the political features of local land use planning if they are to be successful.

The Politics of Planning

Any effort to improve the use of science in public conservation planning must account for the social dynamics of conservation planning processes, and the myriad ways in which "science" is perceived, embraced, or rejected by the various social actors who participate in such processes. This is true nowhere more than in local land use planning. Unlike state and federal regulatory agencies, whose administrative rule-making procedures and regulatory decisions are dictated by a complex system of administrative law that purports to rely primarily on "objective" and "rational" decision-making insulated from "politics," local land use planning is inherently political. Planning directors face their direct employers, all of whom are accountable to the general public through direct election, on a weekly basis when city councils and county boards of supervisors or commissioners meet to make decisions on local land use issues. Unlike most administrative rule-making, the public (i.e., the voters) is in direct attendance in these meetings. Efforts to incorporate "science" into conservation planning processes must therefore directly address the political features of local land use planning if they are to be successful.

This paper explores and illustrates this observation through close examination of two sequential but similar efforts to conduct science-based conservation planning in two adjacent counties in the Sierra Nevada region of California. These cases show not only that planning is political, but that "science" is also rarely pure science when it is incorporated into planning processes. Of these two cases, the successful effort had: (1) a rhetorical framing strategy that emphasized broadly-supported anthropocentric goals, rather than narrower biocentric goals; (2) relatively weak science or spatial detail on where biologically important resources were distributed until broad political support for the program had been achieved; (3) leadership by political actors with very different political philosophies and constituencies, rather than from a single perspective; (4) a sophisticated development community with large players who were experienced with working in complicated regulatory environments; (5) strict state and federal regulatory regimes that could constrain development unless a comprehensive strategy was developed; and (6) little organized opposition by commodity extraction industries, as well as organized support by agricultural businesses. The lessons learned from comparing these cases suggest strategies for incorporating science into public planning processes that will increase the likelihood of successful conservation outcomes.

The Setting and the Cases

The Sierra Nevada region has experienced tremendous growth over the past three decades, accompanied by significant social, cultural, economic, demographic, and ecological change. This growth has been concentrated in resort and recreational communities (clustered around the Lake Tahoe basin, Mammoth Lakes in the eastern Sierra, and several gateway communities near Yosemite National Park), and in the western foothill communities within commuting distance of the greater Sacramento metropolitan area. The foothill communities have absorbed the greatest absolute growth and increased their social and economic diversity and complexity (Duane 1996, Duane 1999). Rapid growth has also generated increased interest in stricter land use regulation, more comprehensive planning, and greater land conservation activity through local land trusts in these communities. However, it has also generated intense social and political conflict over how best to manage that growth.

Two of the most rapidly-developing Sierra Nevada counties recently attempted to develop comprehensive efforts to manage growth in ways that will conserve the amenity, recreational, ecological, and agricultural values of open space. These efforts were facilitated by the non-profit Sierra Business Council (SBC), an organization dedicated to sustaining the Sierra Nevada economy without harming its environment. SBC was funded through grants from the David and Lucile Packard Foundation's Conserving California Landscapes Initiative (CCLI).[1] The two

1. This article is based on research conducted for an external evaluation of the first five years (1998-2002) of the CCLI program. The CCLI program granted SBC a total of $2.36 million in two grants for these programs, and the grants were also used to fund two other, smaller SBC efforts. We completed interviews with more than a dozen interview subjects, specifically about the case studies described here (out of 101 interview subjects in the overall CCLI program evaluation). We also relied extensively on primary Placer Legacy and NH 2020 documents and on secondary studies of the two counties and their respective public conservation planning processes.

counties' efforts generated very different outcomes, however, offering an opportunity to explore both successes and challenges in public conservation planning in the Sierra Nevada. This article evaluates these two ambitious efforts: the Placer Legacy program in Placer County, and the Natural Heritage 2020 program in Nevada County.[2]

Placer Legacy was initially declared a success, as it established an open-space and agricultural conservation program for Placer County in 2000, but NH 2020 failed either to develop a habitat management plan or to establish an open-space district for Nevada County by the time the program was shut down by the Board of Supervisors in 2002. Perhaps more importantly, the NH 2020 process generated a political backlash that has probably set back conservation planning in the Sierra Nevada by five to ten years. Both the Nevada County and Placer County Boards of Supervisors have turned away from the goals and methods of NH 2020 since it generated such controversy in the region. A leading opponent of NH 2020 was elected to the Nevada County Board of Supervisors in 2002, and opponents gained control of the Placer County Board of Supervisors in 2002. NH 2020 played a significant role in both outcomes.[3]

On the surface, the two counties appear very similar, and Placer Legacy's early success appeared to be a model for similar success in neighboring Nevada County. Both counties cut across the Sierra Nevada from the western foothills to the high country near Lake Tahoe. Placer County, however, also includes some of the Central Valley floor and part of metropolitan Sacramento and it includes parts of the Lake Tahoe basin, where land use regulation is controlled by the Tahoe Regional Planning Agency. Nevada County is less proximate to either Sacramento's employment center or to Lake Tahoe, but it is closely linked to both of these economic drivers.

The two programs also followed a similar model, and were coordinated by the same organization, SBC—which should have shown a "learning curve" that would project a higher likelihood of success in Nevada County. Placer Legacy and NH 2020 differed in important ways, however, in their actual implementation. Perhaps most importantly, Placer Legacy emphasized the establishment of strong *political support* for the program before it engaged in the science necessary to establish what would need to be protected through the program. NH 2020, in contrast, attempted to use *science* to establish conservation goals *before* there was strong political support for the conservation goals themselves. There were other differences, of course, but this fundamental difference may offer important lessons for public conservation planning more generally in rapidly-growing rural and exurban regions.

Rationale for the Efforts

These public conservation planning efforts represented a bold initiative to achieve conservation through improved local land use planning in the rapidly-growing Sierra Nevada. The Sierra Business Council had previously completed a project, *Planning for Prosperity,* that highlighted the role that improved land use planning could play in addressing the impacts of rapid growth (www.sbc.org). Based in part upon the 1996 findings of the $6.5 million federally-funded Sierra Nevada Ecosystem Project, both SBC and CCLI recognized that the greatest threats to privately-owned open space in the Sierra foothills were in Placer, El Dorado, and Nevada counties (Duane 1996). Rapid growth threatened agriculture, scenic vistas, public access to open space, and ecological functions as these counties doubled or tripled in just one or two decades.

Both El Dorado and Nevada counties had gone through acrimonious General Plan updates in the early 1990s, leading to bitter election battles and litigation (Duane 1999). SBC therefore decided to begin implementing the *Planning for Prosperity* principles in Placer County, which had updated its General Plan only in relatively uncontroversial areas not otherwise covered by more detailed Specific Plans. Because Placer County had not recently updated its plans and did not have the recent history of political acrimony,

2. For a more detailed discussion of planning in the Sierra Nevada and similar amenity-rich exurban areas, see Duane (1999).

3. The political path from NH 2020 to Placer County's recent election results reflects the political success of NH 2020 opponents in Nevada County, which emboldened Placer Legacy opponents politically in Placer County.

it had both the greatest potential to make changes in its land use plans and the greatest social capital for doing so. Key SBC board members (including the SBC Chair) were also active and well respected in Placer County.

The subsequent effort by SBC to begin the NH 2020 process was based on confidence gained with the remarkable early success of the Placer Legacy effort. Both the Board of Supervisors (BOS) and Placer County citizens endorsed the Placer Legacy program in 2000. A change in political leadership in Nevada County had created an opportunity there beginning in 1999 to engage in a similar process, and the new leadership wanted to implement the recently adopted General Plan through more detailed analysis of open space and habitat management issues. Nevada County is directly adjacent to Placer County, and many conservation problems transcend their common borders. The success of Placer Legacy therefore hinged ultimately on getting neighboring jurisdictions to adopt similar programs. Finally, CCLI had great confidence in both the SBC leadership and the Placer Legacy model after Placer Legacy's impressive early success. The existing capacity of local organizations in the Sierra Nevada is very uneven, making a regional broker like SBC an important player for influencing conservation throughout the region. Its involvement was deemed to reduce the risk that the efforts would be viewed as top-down, regulatory efforts by local government—which would be expected to generate strong opposition in the politically conservative region.

Much of Placer County's growth occurred adjacent to the booming Sacramento metropolitan area, which was growing along the I-80 corridor beyond the city of Roseville into the foothill communities. Much of this pathway for growth is laden with wetlands, necessitating federal wetland conversion permits under Section 404 of the Clean Water Act. Habitat for some species listed under the federal Endangered Species Act was also threatened with development. These regulatory requirements motivated developers to support development of a county-wide approach to mitigation that would avoid project-by-project permitting (especially for an Incidental Take Permit under §10 of the ESA). Agricultural producers were also concerned about suburban development impinging on existing agricultural practices, and they were well-represented by a long-time agriculturalist on the Board of Supervisors. There was consequently a convergence of political support from environmental, development, and agricultural interests in Placer County to develop some kind of open space and biodiversity conservation program.

Political control of the Nevada County Board of Supervisors shifted to a more environmentally oriented 4-1 majority following adoption of a new General Plan in the late 1990s (Duane 1999). The new Board wanted to address open space protection and habitat conservation issues to mitigate the expected impact of future development under the new General Plan, which had been adopted by the previous Board. Unlike neighboring Placer County, however, there were no significant federal regulatory constraints (through the Endangered Species Act or the wetlands permitting requirements of the Clean Water Act) on future development. The county also has relatively little productive agriculture. Neither development interests nor agricultural interests therefore saw a need for a comprehensive open space and biodiversity conservation program.

The efforts that were developed in these two counties followed a similar initial design, but they have had very different outcomes. The Placer Legacy effort, initiated in April 1998, generated social capital and a strong political coalition that by July 2000 had achieved a remarkable consensus among the Placer County Board to protect 75,000 acres of agricultural, open space, and habitat lands over the next twenty years. Placer Legacy was expected to be funded by a combination of state and federal grants and an increased sales tax. Voters endorsed the program in November 2000 by 56 percent to 44 percent, but the same day they also rejected a local quarter-cent sales tax as the primary funding mechanism by an overwhelming margin of 73 percent to 27 percent. Voters agreed with the ends, but not necessarily the means of achieving those ends. In short, they wanted somebody else to pay for their open space.

Since then, the Placer Legacy effort has focused on development of a Habitat Conservation Plan under the federal Endangered Species Act, and a Natural Communities Conservation Plan under California state law to address endangered species issues. These are necessary to address federal permitting requirements and allow development to proceed under existing city and county general plans. The HCP and NCCP have not yet been adopted, however, and no major changes in land use regulation have yet been made by the County in response to the Placer Legacy effort. Some interviewees expressed concern that the measures that will be adopted under the program will be inadequate to address the threat to resources in the county. In particular, potentially negative environmental impacts of various agricultural practices have not been addressed in the Placer Legacy process. The focus of the program is on conserving open space from development. On-the-ground ecological outcomes are therefore difficult to determine from broad estimates of acres maintained in agricultural use.

The Placer County Board committed $1.3 million through 2003 toward habitat acquisition, which will help to translate Placer Legacy's planning efforts into on-the-ground protection. A total of $3 million in additional acquisition funding had also been secured from state and federal grants. A comprehensive "Placer County Conservation Plan" has now been developed in an effort to get 50-year Incidental Take Permits from the U.S. Fish and Wildlife Service under Section 10 of the ESA, and from the California Department of Fish and Game under Section 1600 of the state Public Resources Code. The entire program would also streamline permitting from the U.S. Corps of Engineers under Sections 404 and 401 of the Clean Water Act, and permitting for Streambed Alteration Permits from the Department of Fish and Game under similar state statutes. It is projected to cost $1.3 billion over 50 years of implementation, but those costs would be borne primarily by new development to accommodate another 90,000 housing units by 2050.[4]

In contrast to Placer Legacy's apparent success, the NH 2020 effort in Nevada County was an unqualified disaster. It was intended to produce a habitat conservation program and to establish an open space district to begin to implement such a program, but it achieved neither. The NH 2020 effort also exacerbated existing political fragmentation and polarization in the County, while generating a political backlash that caused a 180-degree turn in the direction of its Board on land use and environmental issues. The NH 2020 program therefore did more than fail to achieve its stated goals: it actually set back conservation in the Sierra Nevada.

Even vocal opponents of the program, who achieved success that has reverberated far beyond Nevada County's borders, have expressed regret about the social polarization and personal vilification that accompanied their success. Nevada County had already experienced highly polarized, winner-take-all politics over the previous decade (Duane 1999), but NH 2020 has left a legacy of bitterness that may take decades to overcome. Two NH 2020 supporters on the Board of Supervisors were defeated for re-election in November 2002, shifting power from a 4-1 environmentally-oriented Board back to a 3-2 pro-growth majority. (One of the leading and most vocal opponents of NH 2020 was elected in November 2002.) One of the two remaining environmentally-oriented incumbents decided against seeking re-election in 2004, while the other was defeated. The Nevada County Board is therefore unlikely to support development of any new habitat management plan or open space district until new elections.[5]

The same strategies that killed NH 2020 are likely to stymie future efforts to incorporate science-based conservation principles into land use planning in Nevada County and elsewhere in the Sierra Nevada; indeed, some NH 2020 opponents then organized to oppose the Placer County HCP/NCCP process in 2003-

4. Powerpoint presentation to the Placer County BOS, March 8, 2005, at http://www.placer.ca.gov/planning/legacy/3-8-05-bos-nccp-presentation/slide1.htm.

5. NH 2020 might have been even more disastrous: a strict private-property-rights initiative on the November 2002 ballot, spawned in large part by NH 2020, would have required government compensation for a wide range of normally permissible land use regulations. Fortunately, however, that measure was defeated by a 57 percent to 43 percent margin county-wide-so at least public land use planning and regulation more generally were not eviscerated in a "throw-the-baby-out-with-the-bathwater" reaction to the NH 2020 debacle. Voters seemed swayed by concerns that the local measure would have bankrupted the county and burdened local taxpayers excessively.

Perhaps most importantly, however, the failure of NH 2020 presents an opportunity to learn from the experience in order to avoid the same mistakes in future public conservation planning efforts.

2004. Despite the NH 2020 disaster, however, there are several positive outcomes: (1) a solid Natural Resources Report was developed by NH 2020 consultants (with assistance by a Science Advisory Panel) for Nevada County, which could serve as the basis for future analysis of development projects that threaten conservation values; and (2) some working-group recommendations were supported by a consensus of working-group members, so they could provide the basis for common ground on policies that could protect working agricultural and forested landscapes. Perhaps most importantly, however, the failure of NH 2020 presents an opportunity to learn from the experience in order to avoid the same mistakes in future public conservation planning efforts.

Key Factors Driving the Different Outcomes

Because the outcomes diverged so widely for Placer Legacy and NH 2020, it is important to note several key differences between the two programs and, to some extent, the two counties. Among the differences that might be significant are (Table 1):

- *Degree of Political Conservatism*. Both counties are conservative politically,[6] so differences in political ideology alone cannot explain the different outcomes. Placer County is more dominated by suburban residents, however, who are typically employed in the Sacramento metropolitan area and more moderate politically. Nevada County has more retirees and more self-employed residents, and its greater physical isolation from urban California may support more radically conservative views.
- *County Politics*. Placer County politics have historically been less polarized than Nevada County politics, which had seen an abrupt transfer of power from a pro-growth 4-1 Board majority in 1992 to a slow-growth 4-1 majority in 1999 (Duane 1999). The degree of control held by these respective Nevada County Board majorities concealed a much narrower margin of control among the electorate, however, because several key elections had been decided by razor-thin margins. The NH 2020 process therefore proceeded (beginning in 2000) with a higher level of political confidence by those pushing the program than was probably warranted by the actual level of political support for the elected Board. (In fact, some of the program's natural allies, emboldened by the election results, were even impatient with the NH 2020 process—believing they could achieve similar outcomes more quickly through less collaborative means. Such arrogance alienated and mobilized NH 2020's opponents.) Placer County politics were less fragmented, while political control in Nevada County has been determined by more fragile coalitions and the shifting whims of a few voters in swing-seat elections.
- *Political Influence of Extractive Industries.* Placer Legacy was developed in a county that is already overwhelmingly suburban, with roughly three-quarters of the population living in cities in the Sacramento Valley or lower foothills. The continuing political power of historic extractive industries is therefore relatively small. Nevada County is at an earlier stage in the exurban transition, however; a much larger fraction of the county remains undeveloped, and extractive industries (e.g., timber harvesting) continue to play a significant role both politically and on the landscape. As the NH 2020 process was unfolding, the Nevada County Board took several policy positions that challenged extractive industries and negatively affected the prospects of NH 2020 being adopted with broad support: (1) support of a "Wild and Scenic River" designation for the South Yuba River, (2) opposition to the federal Forest Service's most logging-intensive management plans, and (3) support of stricter state regulation of clear-cuts on private lands. These positions alienated and mobilized extractive-industry stakeholders with concerns about whether such policies might be adopted or how they might be implemented at the state or federal level. In contrast, the Placer County Board did not face very much political debate or public attention on these issues.

6. Placer County now has a higher percentage of registered Republicans than any other county in California.

Table 1

Characteristic	Placer Legacy	NH 2020
Degree of Political Conservatism and Degree of Metropolitan Integration	Moderately high; suburban and rural	Very high; rural, more isolated
County Politics	Moderate	Polarized
Political Influence of Extractive Industries	Low; dormant	High; mobilized
Sophistication of Development Community	High	Low
Economic and Social Conditions	Strong growth; pre-9/11	Weakening; post-9/11
Other Timing Issues	Unprepared opposition	After Placer Legacy
Base of Support	Leaders from both sides	Environmentalists
Presentation of Goals	Anthropocentric	Biocentric
Terminology	Legacy	Natural Heritage
Leadership Experience	Home-grown	Imported
Land Use Regulation	No land use regulation	More regulation likely
Scientific Information	Weak; outdated	Strong; updated
Outcome	Strong public support	Political backlash

- *Sophistication of Development Community*. Placer Legacy was proposed in a real-estate market that had much larger development firms and subdivision proposals, and therefore a generally more sophisticated development community. Facing endangered species issues and wetlands permitting issues that could constrain development, the development community acknowledged that mitigation would be required and wanted a wide range of well-funded options —preferably financed by the county population as a whole rather than solely through development mitigation fees. Placer Legacy offered developers the possibility of: (1) a county-wide endangered species program that would avoid the need for project-specific permits; (2) identified mitigation sites through that county-wide program; and (3) public funding that would help cover mitigation costs.[7] In contrast, there were not comparable benefits for Nevada County developers because they did not face the same legal constraints under either the Endangered Species Act or the Clean Water Act.

- *Economic and Social Conditions.* The state and national economies began to decline in 2000, just as Placer Legacy was being adopted and NH 2020 was being initiated, generating some economic insecurity and increasing focus by voters on economic matters. The terrorist attacks of September 11, 2001 also created intense insecurity and fear among Americans that played out in the NH 2020 process, as NH 2020 opponents tried to link the Board of Supervisors and NH 2020 to international environmental programs associated with the United Nations that were characterized as threatening American cultural values. This was a potent charge in the politically conservative Sierra Nevada. The conspiratorial link to the UN was never pursued by Placer Legacy's opponents, who focused on the fiscal impact of the plan when it was before the Board and voters in 2000.[8] The Placer Legacy votes also occurred before 9/11,

7. Indeed, the proposed Placer County Conservation Program highlights that permitting approval under the county-wide PCCP approach will take only six months, compared to more than two years on a project-by-project basis.

8. Opponents of government land use regulation in rural California have gone so far as to claim that such efforts are part of a calculated program of "rural cleansing" designed to eliminate independent-thinking rural citizens from the land-thereby making them dependent on urban elites who would then subjugate them for the urban elites' needs.

while there has been increased concern about international challenges to American democracy and values since 9/11.

- *Other Timing Issues*. Because Placer Legacy preceded NH 2020, NH 2020 opponents had more time to mobilize in response to the early success of Placer Legacy. Early opposition did not emerge against Placer Legacy, so it was never challenged in the highly organized way that NH 2020 was. Placer Legacy only generated opposition *after* the Placer County Board had already adopted it in July 2000,[9] and then only from taxpayer groups rather than property-rights groups and anti-environmentalists. These groups succeeded in blocking voter approval in November 2000 for the quarter-cent sales tax originally intended to fund the Placer Legacy program, however, so they have slowed down its implementation.[10]
- *Base of Support.* Placer Legacy was initiated with support from two County Supervisors who hold very different political ideologies, who gave each of their respective constituencies a level of comfort that allowed trust to form among stakeholders who were otherwise wary of each other. In contrast, NH 2020 was initiated by a slow-growth-oriented Board, and was visibly identified with its most environmentally-oriented members. This led some key stakeholders to feel disempowered, and therefore reduced the chances of a collaborative process to build social capital that could bind the historically fractious community.
- *Presentation of Goals.* Placer Legacy explicitly defined the goals of the program broadly and in anthropocentric terms, placing agriculture and open space ahead of biodiversity protection as rationales for the program. In contrast, NH 2020 in its primary documents focused mainly on conserving biodiversity; the program treated open space and the protection of working landscapes as merely a means to the end of protecting biodiversity, rather than as goals in themselves. The Placer Legacy approach had broader appeal, and therefore avoided labels of environmental extremism.
- *Terminology/Rhetoric.* Placer Legacy's very title emphasized the responsibility of today's residents for the inheritance of future generations, while NH 2020's title ("Natural Heritage 2020: A Vision for Nevada County") emphasized "natural" and unfortunately used a term ("heritage") that opponents associated with programs proposed by the United Nations and the Clinton administration. Although these national and international programs actually had nothing to do with NH 2020, the terminology and rhetoric allowed opponents to make links that raised concerns among conservative voters when they went unanswered.[11]
- *Leadership Experience.* Placer Legacy was led by locally experienced Placer County planners with extensive social and political networks in the county, and SBC's staff played a sophisticated role in managing the politics of gaining a 5-0 Board vote in support of the initiative. In contrast, NH 2020 was led by county planning staff who were new to Nevada County, and therefore did not have the social or political networks (or personal reputations) necessary to manage the political firestorm that erupted. Key leadership changes at SBC also meant that SBC did not manage the political dimensions of NH 2020 as effectively as it did Placer Legacy. Finally, the initial SBC staff person leading NH 2020 was previously associated with a local environmental advocacy group, which immediately generated suspicion among key NH 2020 opponents. This initial mishap proved difficult to overcome later, when SBC made staff changes in the NH 2020 program.

9. SBC strategists tried to minimize opposition during the Board vote by ensuring that some strong proponents from the environmental community did not speak publicly in favor of the program-because doing so probably would have mobilized opposition to the program and made it politically difficult for some Supervisors to support it.

10. More recently, opponents have also had some success at the polls by electing several new supervisors who are not supportive of the Placer Legacy program. The reality of ESA and CWA regulation make the Placer County Conservation Plan an attractive alternative for the development community, however, compared to strict regulation.

11. As both George Lakoff (1996) and Holly Doremus (2000) note, framing and rhetoric matter in political discourse.

- *Commitment to Changes in Land Use Regulation.* Placer Legacy began with an explicit commitment *not* to change any land use designations or regulations, while NH 2020 was designed to create a habitat management plan that could then be the basis for open space acquisition or land use regulation. The Placer Legacy program explicitly indicated that regulation would not be the means of conserving open space and agricultural land, and focused instead on identifying priorities and financing for land acquisition only from willing sellers. While many observers believe land use regulation will ultimately be necessary to achieve the program's stated goals, this initial commitment against changing land use regulations and zoning designations allowed Placer Legacy to avoid anti-regulatory backlash (common in the conservative region) against the program from the outset. This in turn helped build broad support for the overall program's goals. Now Placer Legacy can explore the complementary use of other means (e.g., regulation) for achieving those broadly supported goals. Moreover, the County can do so by focusing on regulatory processes (under the ESA and CWA) where the federal government can take the heat as the environmental regulator.
- *Scientific Information.* Placer Legacy relied on outdated maps and incomplete natural resources inventories, focusing on the process of building consensus before trying to identify what should be conserved.[12] Only now, after achieving a broad political consensus, has Placer County quietly shifted its focus to improving background data and identifying conservation priorities. The science used to support development of broad political support for the Placer Legacy program therefore did not include spatially explicit mapping that could be used by opponents to mobilize opposition to the program. Instead, program organizers ensured broad support for the goals of Placer Legacy before engaging the difficult social, economic, and political tradeoffs that might be necessary to achieve those goals. Placer Legacy was therefore not really a "science-based" initiative.

In contrast, NH 2020 immediately initiated a comprehensive update of scientific information that could easily be translated into maps that highlighted areas warranting conservation. A scientific advisory panel was established to ensure that the NH 2020 program would have a stronger science foundation than that employed in Placer Legacy. That stronger science base was then translated into spatially explicit habitat needs, and identified priorities for land conservation through either land use regulation or possible acquisition of development rights on critical parcels. These detailed maps reflected better science than that used in Placer Legacy, but they also allowed property-rights activists to identify specific land owners who might face constraints on development if a habitat management plan were adopted. The activists were then able to mobilize some of those land owners to oppose the entire NH 2020 program due to concerns about how the NH 2020 program might affect their own future development potential.

Neither Placer Legacy nor NH 2020 appeared to utilize scientific information in an effective way: Placer Legacy failed to make its program science-based, so there is some risk that the program will fail to achieve its ecological goals; while NH 2020 failed to gain broad understanding and support for scientific principles before translating those principles into maps that threatened other social, economic, and political values. A more effective model would be one where scientific principles are incorporated into a planning process that recognizes the potential for such principles to conflict with other social, economic, and political values when those principles are translated into conservation plans. In doing so, the planning process could identify mechanisms to mitigate such conflicts so that key stakeholders do not feel their interests are threatened by conservation. Placer Legacy still has the potential to do this as it improves its science and identifies specific areas for conservation. Nevada County faces a climate of mistrust and antagonism, however, that makes it difficult to do science-based conservation plan-

A more effective model would be one where scientific principles are incorporated into a planning process that recognizes the potential for such principles to conflict with other social, economic, and political values when those principles are translated into conservation plans.

12. It is unclear whether this was a deliberate strategy or simply an artifact of underlying data deficiencies stemming from the way the 1994 General Plan had been updated. Either way, however, ambiguity proved useful politically, in that the specific consequences (in both regulatory and fiscal impacts) of the program remained fairly abstract.

ning. Laying the political groundwork for a program therefore seems to be an essential step if planners want to incorporate science more directly into conservation land use planning.

Lessons from the Cases

The causes and consequences of the different outcomes between Placer Legacy and NH 2020 are complex, but it appears that the most important lessons from the cases are relatively simple: (1) conservation programs that involve public land use planning and regulation must be tailored to fit the local social and political context, and mischaracterizations of such programs must be responded to quickly and professionally; and (2) the existence of a strong state and federal regulatory regime can serve as an incentive for the development of more comprehensive local plans that offer less oversight on a project-by-project basis, but a broader set of incentives must be developed to overcome political resistance to conservation programs that conflict with other social, economic, and political values. Effective conservation planning must address these conflicting values or else face a political backlash. Both the carrot and the stick must be employed to reduce opposition to conservation planning.

"Getting the science right" is also insufficient if either the people doing the science are not trusted by key stakeholders, or the values that define the purposes of that science are not widely shared. NH 2020 attempted to hide behind an "objective" veneer that emphasized science without acknowledging that the science would be put to particular purposes that reflected particular values. Not surprisingly, people who either did not share those values or mistrusted the people espousing them reacted strongly to a perceived threat to other values that they cherished.

"Collaboration" is also a difficult process when it is initiated and controlled by a group in power. The theory of communicative action is premised on all of the stakeholders having equitable power (Duane 1997), and this was not the case in the NH 2020 process. While NH 2020 eventually opened its doors to all, early exclusion of some key stakeholders created mistrust that was never overcome. In fairness, the opponents of NH 2020 also resisted efforts to include them in the process; they were more interested in stopping NH 2020 than being part of it. Even NH 2020's natural allies were lukewarm to aspects of the program, however, so there was no strong coalition to counter opponents' claims when NH 2020 was attacked. Both SBC and Nevada County staffers therefore felt isolated and relatively ineffective in responding. The lack of a clear, coherent, and professional public relations and political strategy – something that had not been necessary for Placer Legacy – was then revealed.

Believing they could win the case with the broader public on the merits alone, NH 2020 supporters relied on their tenuous hold on political power to push the program through against vocal opposition. This approach failed to recognize that NH 2020 was a complicated effort to address a long-term problem that was difficult to explain to the public. The opposition was therefore able to define NH 2020 for the public, misrepresenting the program in ways that tapped into underlying political resistance to government regulation. Consequently, the public never got to judge the program on its merits.[13] The resulting political backlash—where the political leaders of the NH 2020 program were sent out of office in favor of the opponents of NH 2020—is not surprising.

Placer Legacy faces a different risk: while there has been strong public support for the program, fear of an NH 2020-type backlash may keep Placer County from pushing too hard for genuine and meaningful conservation when stakeholder interests diverge. This is especially important regarding conservation on working agricultural landscapes, where some management practices may conflict with important biodiversity values. The challenge in Placer Legacy is therefore to begin to tackle the harder choices that require tradeoffs among goals. The program otherwise runs the risk of having good politics built on bad science—and the result could be ineffective conservation that fails to protect ecological values. Such a politically accept-

13. Many of the claims challenging NH 2020 were factually inaccurate regarding the actual regulatory authority under consideration at the time, but the opponents were correct in claiming that NH 2020 would lead to new restrictions on private property while increasing the role of government and biodiversity conservation as a privileged public value.

able but ecologically inadequate plan could result in the social, economic, and ecological "train wrecks" that so commonly generate criticism of the federal Endangered Species Act. Placer Legacy cannot be judged a success unless it can avoid such train wrecks in the future. It is still too early to judge if the Placer County Conservation Plan can meet that test substantively.[14]

In summary, Placer Legacy and NH 2020 illustrate the challenges of public conservation planning. Planning is inherently a socially contentious process, for it often pits conflicting values and interests against each other. Developing and implementing such plans are therefore always going to be challenging. Based on these two case studies, however, successful public conservation planning seems to require caution and deliberation while building broad-based political support for both the goals and the means of managing growth to achieve conservation. Stakeholders must agree on the purpose and rationale for conservation planning if science is going to be accepted as a foundation for developing a "science-based" conservation plan. Otherwise, political conflict will overshadow the science and make it socially illegitimate.

Success cannot be measured by political consensus alone, however, for the sustainability of both conservation plans and communities depends on ecologically viable landscapes. The real test of any conservation planning regime is therefore both its political durability and ecological viability. By this standard, it is premature to call even the Placer Legacy program a successful program. The real test will be whether or not it can accommodate social and economic needs while ensuring ecologically functioning systems that conserve biodiversity over time. Science has an important role to play in determining ecological viability. Political agreement on a plan's desirability must still be tested through scientific monitoring and evaluation of its approach.

14. Even if there is a strong political consensus that a strategy is adequate, the appropriate substantive test of any plan should be whether or not enough habitat is protected to ensure functioning ecological systems and biodiversity. Whether state and federal regulators consent to the plan should be linked to those outcomes.

Good science may need good politics to be effective in guiding public conservation planning, but it is not necessarily apparent that good politics will always embrace good science. We must therefore watch Placer Legacy carefully to see if the quality of its conservation can match the rhetoric that generated broad political consensus in support of the program.

Literature Cited

Doremus, Holly. 2000. The rhetoric and reality of nature protection: Toward a new discourse, 57 *Washington & Lee Law Review*. 11.

Duane, Timothy P. 1996. "Human Settlement, 1850-2040" in *Sierra Nevada Ecosystem Project, Final Report to Congress*, *Volume II (Assessment and Scientific Basis for Management Options)*, Wildland Resources Center Report No. 36, University of California, Davis, June, pp. 235-360. www.ceres.ca.gov/snep (Accessed February 27, 2007)

Duane, Timothy P. 1997. Community participation in ecosystem management, *Ecology Law Quarterly*. 24 (4): 771-797.

Duane, Timothy P. 1999. *Shaping the Sierra: Nature, Culture, and Conflict in the Changing West*. Berkeley: University of California Press.

Lakoff, George. 1996. *Moral Politics: How Liberals and Conservatives Think*. Chicago: University of Chicago Press

The author benefited from comments by participants at the Banff Centre's conference on Sustainable Mountain Communities, Banff, Alberta, Canada (June 2003), and the Mountain Geography seminar at the University of California, Davis (October 2003). The author appreciates comments on an earlier draft of this article by Jim Leape, Jennifer Holthaus, Michael Mantell, Steve Johnson, Andrea Peterson, and Rebecca Kihslinger. This research was funded by the David and Lucile Packard Foundation, but the author is responsible for the findings in the article

Effective conservation planning must address these conflicting values or else face a political backlash. Both the carrot and the stick must be employed to reduce opposition to conservation planning.

For more than three decades, the Environmental Law Institute has played a pivotal role in shaping the fields of environmental law, management, and policy domestically and abroad. Today, ELI is an internationally recognized, independent research and education center.

Through its publications and information services, training courses and seminars, research programs and policy recommendations, the Institute activates a broad constituency of environmental professionals in government, industry, the private bar, public interest groups, and academia. Central to ELI's mission is convening this diverse constituency to work cooperatively in developing effective solutions to pressing environmental problems.

The Institute is governed by a board of directors who represent a balanced mix of leaders within the environmental profession. Support for the Institute comes from individuals, foundations, government, corporations, law firms, and other sources.

Environmental Law Institute

2000 L Street, N.W., Suite 620

Washington, D.C. 20036

Telephone: (202) 939-3800

Fax: (202) 939-3868

www.eli.org

ENVIRONMENTAL LAW • INSTITUTE®