Planning for Biodiversity Conservation: Putting Conservation Science into Practice

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The growing recognition that the species extinction crisis has deepened and that there are limited conservation dollars to address this crisis has had a profound influence on the planning methods and conservation strategies of governmental and nongovernmental organizations. For example, World Wildlife Fund (WWF) and Conservation International have pinpointed priority ecoregions and biodiversity "hotspots," respectively, that represent some of the most significant remaining regions for conserving the world's biological diversity (Olson and Dinerstein 1998, Myers et al. 2000). Both The Nature Conservancy (TNC) (Master et al. 1998) and World Wildlife Fund (Abell et al. 2000) have set conservation priorities at the scale of large watersheds for freshwater ecosystems in the United States. The National Gap Analysis Program (GAP) of the US Geological Survey's Biological Resources Division is using biological survey data, remote sensing, and geographic information systems (GIS) technology at the state level to identify those native species and ecosystems that are not adequately represented in existing conservation lands—in other words, the aim of the program is to detect conservation "gaps" (Jennings 2000). Some state governments in the United States are also developing their own biodiversity conservation plans (e.g., Kautz and Cox 2001).

A SEVEN-STEP FRAMEWORK FOR DEVELOPING REGIONAL PLANS TO CONSERVE BIOLOGICAL DIVERSITY, BASED UPON PRINCIPLES OF CONSERVATION BIOLOGY AND ECOLOGY, IS BEING USED EXTENSIVELY BY THE NATURE CONSERVANCY TO IDENTIFY PRIORITY AREAS FOR CONSERVATION

Internationally, more than 175 countries are mandated, as signatories to the United Nation's Convention on Biological Diversity, to prepare National Biodiversity Strategy and Action Plans (Secretariat of the Convention on Biological Diversity 2000).

All of these assessments and priority-setting exercises have a common trait: They focus on relatively large spatial areas or regions inhabited by thousands of species and hundreds of identifiable natural communities. To implement conservation

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actions on priorities identified in these coarse-scale assessments requires a practical yet science-based planning framework for the conservation of biodiversity *within* these regions. Recognizing that most conservation efforts are reactive and that its own conservation investments needed to be more strategic, The Nature Conservancy has been developing such a framework for conservation planning in terrestrial, freshwater, and near-shore marine environments (Groves et al. 2000). This framework has been tested and revised through the preparation and implementation of over 45 ecoregional and regional conservation plans in the United States (figure 1), Latin America, the Caribbean, Micronesia, and Yunnan, China. The framework's methods are based on theories and principles from ecology and conservation biology and have been developed in consultations with scientists from research, natural resource management, and conservation institutions and organizations. It has been applied across many types of ecosystems by numerous scientists and practitioners under a variety of levels of funding and availability of information. In this article, we report the lessons learned from implementing TNC's planning framework as a model for the many agencies and institutions around the world that face similar challenges in conservation planning.

Four significant scientific advances in the last decade of the 20th century have shaped the development of this framework. First, the growing list of endangered species highlighted the need for approaches to conservation that are proactive and complement the reactive measures of most endangered species programs. Second, scientists increasingly recognized the importance of conserving the underlying ecological processes that support the patterns of biological diversity (e.g., Balmford et al. 1998). Third, we began to realize that biodiversity occurs at multiple spatial scales and levels of biological organization (Schwartz 1999) and that a greater emphasis to conserve this diversity must be placed at all appropriate levels and scales (Poiani et al. 2000). Finally, we learned that systematic conservation planning approaches are more effective at conserving biological diversity than are the ad hoc approaches of the past (Margules and Pressey 2000). These ad hoc approaches have resulted in a biased distribution of lands and waters set aside for conservation purposes, with the majority of these areas occurring at relatively higher elevations and on steeper slopes and poorer soils (Pressey et al. 1996, Scott et al. 2001).

TNC's seven-step, conservation planning framework incorporates all four of these scientific advances (see box 1). We have applied the framework to ecoregions—large areas of the earth's surface that have similarities in faunal and floral composition due to large-scale, predictable patterns of solar radiation and moisture (Bailey 1998). Most ecoregional classifications are based upon criteria such as climate, soils, geology, vegetation cover types, or in the case of marine systems, oceanographic factors (Bailey 1998), because these environmental variables are assumed to have a major influence on the evolutionary history and distribution of many species and communities. The US Forest Service and the US Environ-

Box 1. A Seven-Step Conservation Planning Framework

Step 1: Identify conservation targets

Communities and ecosystems

Abiotic (physically or environmentally derived targets)

Species: imperiled or endangered, endemic, focal, keystone

Step 2: Collect information and identify information gaps

Use a variety of sources

Rapid ecological assessments, rapid assessment programs

Biological inventories

Expert workshops

Step 3: Establish conservation goals

Two components of goal: representation and quality

Distribute targets across environmental gradients

Set a range of realistic goals

Step 4: Assess existing conservation areas

Gap analysis

Step 5: Evaluate ability of conservation targets to persist

Use criteria of size, condition, and landscape context

Use GIS-based "suitablity indices"

Step 6: Assemble a portfolio of conservation areas

Use site or area selection methods and algorithms as a tool

Design networks of conservation areas employing biogeographic principles

Step 7: Identify priority conservation areas

Use the criteria of existing protection, conservation value, threat, feasibility, and leverage

Figure 1. The Nature Conservancy (TNC) map of the ecoregions of the United States and adjacent regions of Mexico and Canada, as adapted from Bailey (1995). The different colors represent the boundaries of distinct ecoregions. TNC is also working on ecoregional plans in Latin America, the Caribbean, and the Asia–Pacific realms.

mental Protection Agency developed ecoregional classifications for the United States (Omernik 1987, Bailey 1995, 1998), and the World Wildlife Fund has done so for every continent (Olson et al. 2001). For this planning framework, we used a modified version of Bailey's (1995) ecoregions for the United States and relied on WWF's ecoregional classifications for other countries. Although intended for application at an ecoregional scale, this framework should be applicable to other types of planning regions (e.g., Conservation International's biodiversity hotspots) at similar spatial scales. Redford and colleagues (forthcoming) provide an overview of approaches that various organizations use to conserve biodiversity, including the spatial scale at which these different approaches are intended to operate.

The primary product of applying this framework is the identification of a portfolio or network of lands and waters for conserving the elements of biodiversity within an ecoregion. We refer to these lands and waters as *conservation areas.* We separate the identification of conservation areas from their design and management (Scott and Csuti 1997). We emphasize that the primary purpose of regional-scale conservation planning as articulated in this article is to identify a set of conservation areas that best represents the native species and ecosystems of the region and the underlying ecological processes that sustain them. Determining how those areas are best designed and managed requires a more detailed analysis, usually at finer spatial scales. Planning at the scale of conservation areas (e.g., Nature Conservancy preserve, national park, national or state wildlife refuge) aims to maintain or improve the ecological condition of targeted biological or environmental features of these areas and to abate threats to these features (Poiani et al. 1998). Noss and Cooperrider (1994) and Meffe and Carroll (1997) provide overviews of the design and management of conservation areas.

A seven-step framework for conservation planning

Although we describe the framework step by step, the actual planning process is less linear and more dynamic. For example, the collection of information (step 2) occurs throughout the planning process from its inception to the point of setting priorities among the portfolios of conservation areas. Furthermore, the planning process itself should be viewed as adaptive, with continual improvements being made in both the methods of the steps and the conceptualization of the entire seven-step framework. Finally, for each step, we cite relevant scientific literature that provides some substantiation for the importance of the step.

Step 1: Identify conservation targets

For the purpose of this planning framework, we define "biodiversity" as the variety of living organisms, the ecological complexes in which they occur, and the ways in which they interact with each other and the physical environment (Redford and Richter 1999). Although biodiversity is defined many ways, this definition is consistent with one previously advanced by Noss (1990). It characterizes biodiversity as having three primary components: composition, structure, and function. From a conservation perspective, it is necessary to consider each of these components.

To represent the biodiversity of a region or ecoregion in conservation areas, we focus on conservation targets, the entities or features for which a conservation plan or project is attempting to ensure long-term persistence (Redford et al. forthcoming). The word "target" has also been used in a different context by some conservation planners and scientists to imply a particular goal, such as conserving a specific percentage of an ecosystem type (Soulé and Sanjayan 1998). Because it is impractical to conduct planning efforts for each of the hundreds to thousands of species that inhabit any one region, scientists and planners seek to identify a set of conservation targets that presumably represent the biodiversity of a region. These targets may be defined based on their biological features (e.g., species and communities), physical features (e.g., soils, geology, climate), or a combination of both biotic and abiotic features. The assumption is that, by focusing planning efforts on these targets, there will be a high likelihood of conserving the vast majority of living organisms in a region, both those known to science and the many yet to be discovered.

Considerable debate has taken place over which levels of biological organization are most appropriate to serve as targets for conserving biodiversity (e.g., species vs. communities vs. landscapes; Franklin 1993). Some scientists have recommended a "coarse filter" and "fine filter" approach to target selection (e.g., Hunter 1991, Noss and Cooperrider 1994, Noss 1996). The principal idea behind the coarse filter approach is that by conserving representative examples of the different biological communities and ecosystems that occur within a region, the majority of species of that region will also be conserved. Some types of conservation targets, however, such as rare or endangered species, do not always co-occur in a predictable fashion with certain communities or ecosystems. For these targets, individual or fine filter approaches are necessary. Which particular conservation targets can be captured with a coarse filter approach has never been tested empirically (Noss and Cooperrider 1994).

Although the coarse–fine filter strategy is a practical approach to an otherwise complex problem, it can be confusing with regard to the spatial scale at which various coarse and fine filter targets occur. A more useful approach may be to recognize that conservation targets can be identified at a variety of levels of biological organization and spatial scales from local (fine) to regional (figure 2). Which targets are used in any particular planning exercise will depend to a great extent on what information is available (Margules and Pressey 2000). Some areas of the world, such as parts of the United States, Australia, and Europe, are relatively rich in information on individual species. However, many areas are not, particularly those in the tropical regions of the world; thus, some type of conservation target in addition to a species-specific one must be used. The only spatially consistent types of information available in most parts of the world are for physical variables (e.g., elevation, climate, soil type) and for communities

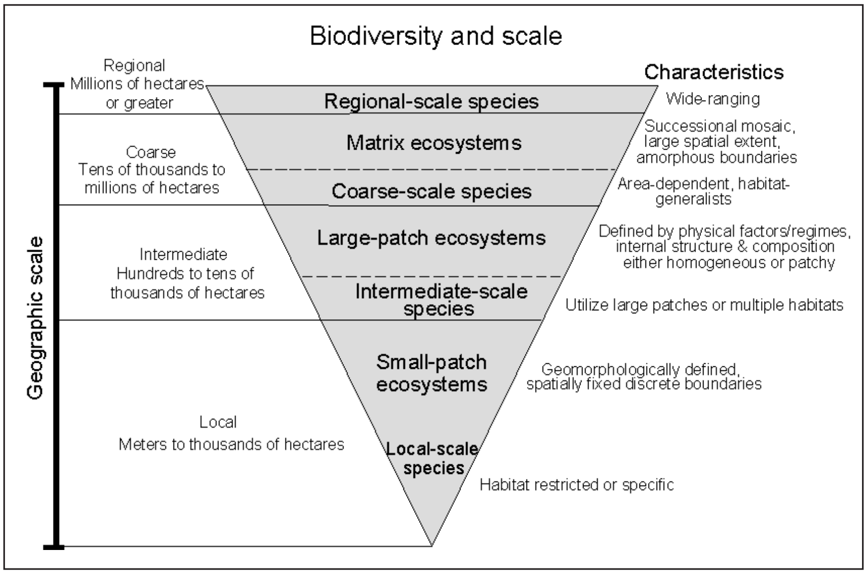

Figure 2. The spatial scales and levels of biological organization. Conservation targets can be viewed as occurring at four spatial scales from local to regional. The general range in size (hectares) for each spatial scale is indicated to the left of the pyramid and some general characteristics of two types of conservation targets (species and ecosystems) are shown on the right. Reprinted from Poiani et al. (2000), with permission.

or ecosystems classified according to vegetative composition. Based on these considerations, we suggest three general classes of conservation targets: (1) communities or ecosystems, (2) abiotic targets based on physical variables, and (3) species not likely to be subsumed under the other two classes of targets.

Communities and ecosystems. Like biodiversity, *community* and *ecosystem* have various definitions. For the purposes of this article "community" refers to an interacting assemblage of species that co-occur with some degree of predictability and consistency. "Ecosystem" includes the interactions of these communities with the abiotic or physical environment, such as through the transfer of energy and matter (Whittaker 1975).

Communities or ecosystems occur at a spectrum of spatial scales (figure 2) and can serve as practical surrogates for sampling finer levels of biological organization. Classifications of communities and ecosystems exist for many parts of the world at local, state, regional, and national scales (see Grossman et al. 1999, table 5, for a summary). Although data on the actual individual community and ecosystem units described in these classifications are often lacking, remote sensing imagery can contribute much information on communities and ecosystems described on the basis of dominant vegetation (Jennings 2000).

The Nature Conservancy and NatureServe (formerly known as the Association for Biodiversity Information), in collaboration with gap analysis programs, have developed an international classification of vegetation communities (Grossman et al. 1998). This classification system is a hierarchical taxonomic structure with physiognomic criteria used at the upper levels of the classification (coarsest spatial scale of resolution) and floristic criteria at the lower levels (finest spatial scale). Because these finer levels of the classification are difficult to detect and map with remote sensing technology, they are generally less useful for regional conservation planning in most parts of the world. Although The Nature Conservancy has used this classification in its ecoregional planning work, its use has largely been restricted to the United States (Groves et al. 2000). Scientists from TNC, gap analysis planners, and NatureServe are now modifying the classification to make it a more geographically robust tool by incorporating a classification level that identifies vegetation communities based on dominant species, that is detectable by remote sensing imagery, and that can be consistently applied across the spatial scale of ecoregions or similarly scaled planning units.

Abiotic targets. The increasing availability of regional, national, and global data sets on environmental variables such as elevation, soil, and geology makes them attractive targets for conservation planning, especially for parts of the world where there is a dearth of biological information. For example, Pressey and colleagues (2000) developed a classification of landscape targets covering all of New South Wales (NSW), Australia, that was derived mainly from abiotic features. The classification system was subsequently used as a surrogate for biodiversity to assess the extent to which conservation areas in NSW are representative of the state's biodiversity. Although environmental factors are known to influence the distribution of many species, other studies have demonstrated that combining abiotic targets with biotic targets results in a system of conservation areas that is more representative of a region's biodiversity (Kirkpatrick and Brown 1994). Several recent planning efforts in Australia (Smart et al. 2000), Papua New Guinea (Nix et al. 2000), the United States (Southern Rocky Mountains Ecoregional Team 2001), and South Africa (Cowling et al. 1999) have used approaches that combine abiotic and biotic targets.

Because of the paucity of biological information available for aquatic species and communities, TNC developed a classification framework for freshwater ecosystems that accomodates biological data, but is based on abiotic variables that have been shown to strongly influence biotic patterns at multiple scales (Lammert et al. 1997, Groves et al. 2000). This classification is used in conjunction with biotic data to inform the conservation planning process. Similar efforts are under way in the National Gap Analysis Program (Jennings 2000). The TNC classification loosely follows the hierarchical model of Tonn (1990); it includes regional-scale units (ecological drainage units) that take into account regional drainage (zoogeography), climatic, and physiographic patterns; mesoscale units (aquatic ecological systems) that are aggregations of local-scale units tied together by dominant ecological processes; and local-scale units (macrohabitats) that are small to medium-sized lakes and valley segments of streams defined by hydrology and map-based criteria (stream size, gradient, connectivity, catchment geology) to represent local environmental patterns and processes (figure 3).

In marine environments, most classification systems are based on a combination of biotic and abiotic units. Biotic units can be either vegetative (e.g., seagrass, saltwater marsh, kelp) or faunal (e.g., oyster, coral). Many marine classifications also include abiotic units (Dethier 1992), especially in offshore environments where there is less biological information (Day and Roff 2000). These classifications, whether described by biotic or abiotic factors, are generally known as "habitat" classifications, although they are often consistent with terrestrial ecosystem classifications. The most promising way to select conservation areas in marine environments is to focus on these habitats and the ecological processes that sustain them, an approach taken by TNC (Beck and Odaya 2001) and others (Ward et al. 1999).

Species. Several categories of species have been identified as being useful for management or conservation purposes (e.g., threatened or endangered, endemic, umbrella, flagship, indicator, landscape, focal, keystone). Because of their rarity, habitat specificity, or area needs, the majority of species in these categories are unlikely to be conserved by a focus on either community or ecosystem or abiotic targets. Most of these categories have received considerable attention in the scientific

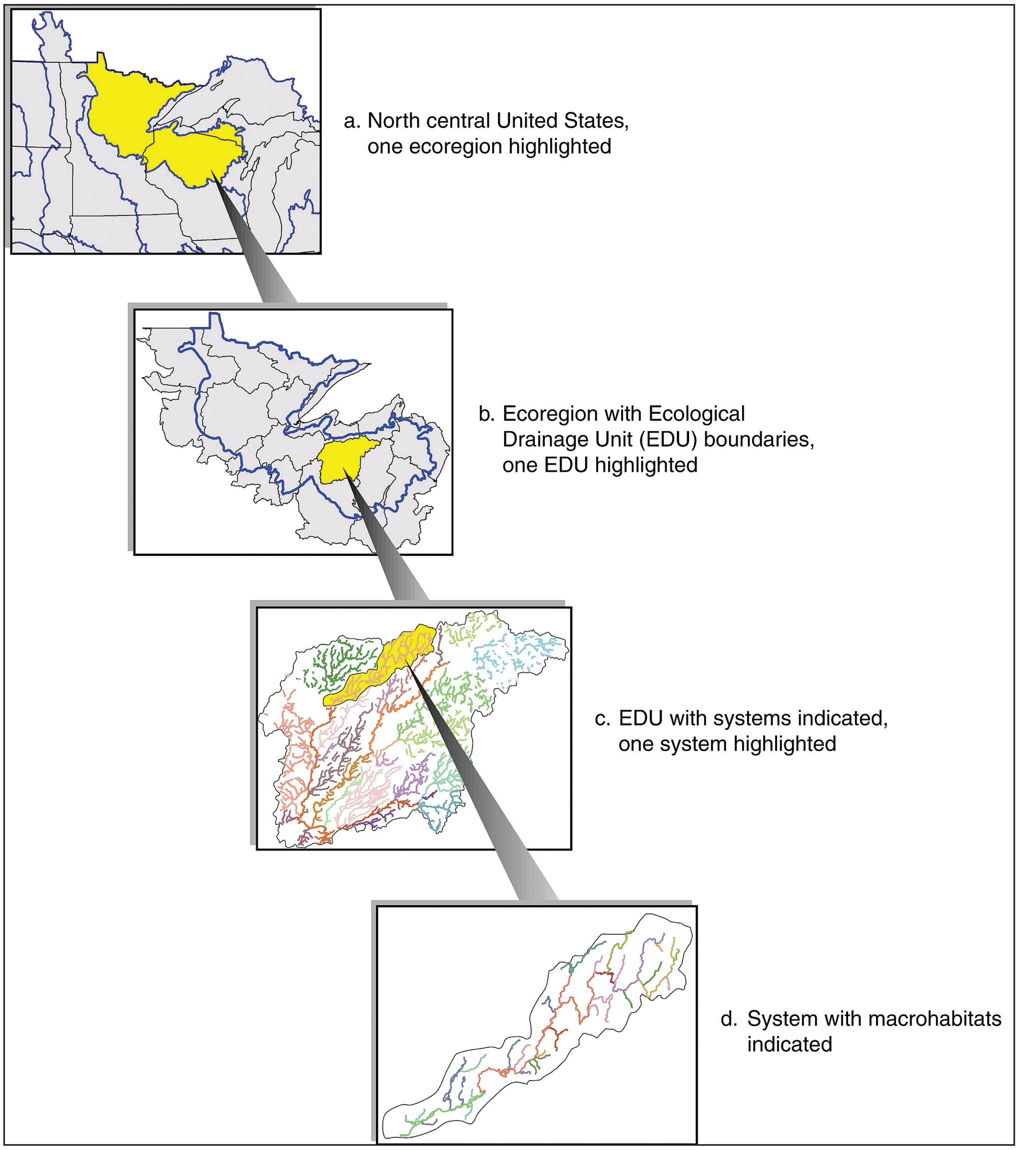

Figure 3. Aquatic classification framework of The Nature Conservancy showing the relationships among the different hierarchical levels of the classification, from ecoregions to macrohabitats. Ecological systems and rare macrohabitats are often selected as conservation targets, especially in the absence of biological information, which is commonly the case in freshwater ecosystems. Ecological drainage units are used to stratify the representation of freshwater conservation targets across environmental gradients.

literature, and several have been criticized on conceptual grounds. Because of questions concerning the utility and validity of flagship, umbrella, and indicator species (see, e.g., Simberloff 1997), this framework emphasizes imperiled, threatened or endangered, endemic, focal, and keystone species as conservation targets.

Imperiled and threatened or endangered species. This category of target species includes those ranked by NatureServe and the network of Natural Heritage programs as globally vulnerable, imperiled, or critically imperiled (for the current listing see *www.natureserve.org*; Master et al. 2000); species listed as threatened or endangered under the US Endangered Species Act (see *www.endangered.fws.gov/endspp.html*); and species listed on the World Conservation Union Red List as vulnerable, endangered, or critically endangered (see *www.redlist.org* for current listing; Hilton-Taylor 2000).

Endemic species. This category consists of species whose entire distribution is restricted to an ecoregion or a small geographic region within an ecoregion. These species make worthy conservation targets because of their limited distribution and associated vulnerability to extinction.

Focal species. Lambeck (1997) defined four types of focal species: area-limited, dispersal-limited, resource-limited, and limited by ecological process (e.g., natural flow regime). Others have defined focal species differently (Noss et al. 1999). For conservation planning purposes, populations of wide-ranging species whose home ranges often exceed that of individual ecoregions are among the most useful focal species (Carroll et al. 2001). Wide-ranging species can be both dispersal- and area-limited. Examples include brown bears, jaguars, sea turtles, and anadromous fishes.

Keystone species. Keystone species have an impact on a community or ecosystem that is disproportionately large relative to their abundance (Power et al. 1996). Although relatively few keystone species (e.g., starfish, beaver) have been identified, their importance to the conservation and function of ecosystems can be substantial (Kotliar 2000).

Step 2: Collect information and identify information gaps

A regional conservation plan for biodiversity requires a variety of data, ranging from human population trends and major land ownership patterns to environmental and biological information on conservation targets (table 1). Fortunately, a great deal of this information is available digitally, and much of it can be found on the Internet (see Groves et al. 2000,

Table 1. Useful categories of information for conservation planning.

Category	Type of information
Land use ownership	Transportation Administrative boundaries Land cover Locations of dams and diversions Water–quality monitoring stations Hydrological flow monitoring stations Point sources for pollution
Physical	Soils Geology Climate Terrain and elevation Wave exposure Wave depth Watersheds and hydrography
Biological	Vegetation cover Wetlands Species distribution Ecoregions and bioregions Shellfish distributions Fisheries data Coral reef distribution and status
Socioeconomic	Population density Population trends Economic trends

appendix A-10, for sources and descriptions). A special issue of *Science* (2000, vol. 289: 2308–2312) that focused on the emerging field of biodiversity informatics provides additional sources for accessing information on biodiversity, including links to a comprehensive list of global databases and Web sites.

The best regional conservation plans utilize information from all available sources, including conservation organizations, public natural resource agencies (local, state, provincial, federal), academia, research institutions, and individual experts. In many cases, critical information necessary for development of a conservation plan may be lacking. These gaps can be filled through use of a variety of techniques that utilize a combination of remotely sensed imagery, reconnaissance overflights, selective biological inventories, and visual display of information with a GIS to cost-effectively gather biological and ecological information about an area; among these techniques are TNC's Rapid Ecological Assessments (Sayre et al. 2000) and Conservation International's Rapid Assessment Programs *(www.biodiversityscience.org/xp/CABS/research/rap/aboutrap.xml)*. Taxon-specific biological inventories can be cost-effective (Balmford and Gaston 1999) and help fill data gaps, especially when the inventories are designed with the intent of providing more accurate estimates of the spatial distributions of species (Margules and Austin 1994). Finally, consultations with experts, often in a workshop setting, have proven extremely useful to both governmental and nongovernmental organizations involved in natural resource management or biodiversity conservation planning (Dinerstein et al. 2000). However, planners need to be aware of some of the assumptions, difficulties, and inherent biases of using expert-based information (Cleaves 1994).

Step 3: Establish conservation goals

Once conservation targets have been identified, planners need to establish explicit goals for them by answering these questions: How much or many of each target should be conserved, and how should these targets be distributed across the planning region? Determining goals is important for several reasons. First, with goals in place, planners can evaluate the effectiveness of a proposed system of conservation areas by asking whether those areas represent the targets at levels requisite for their conservation in the entire planning region (figure 4). Second, goals provide guidance to planners who may have to balance competing demands for lands and waters in the planning region (as happens, for example, when

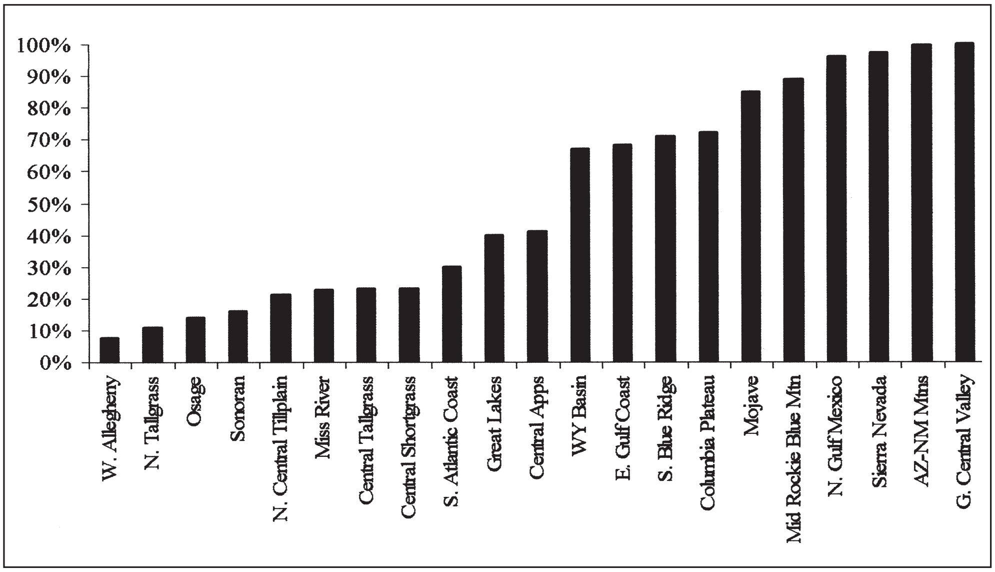

Figure 4. Percentage of conservation targets for which goals were met in several TNC ecoregional plans. "Meeting goals" refers to whether a conservation target is represented a specified number of times in a proposed conservation area across the range of the target within the ecoregion. This graph indicates a general pattern of lower percentages of goals met for ecoregions where natural vegetative cover has been extensively removed or converted. Where conservation goals are not met, it may be necessary to undertake additional biological inventories or restoration efforts. An assessment of conservation goals is one mechanism for measuring the effectiveness of a proposed system of conservation areas.

public agencies operate under multiple-use mandates). Third, goals for targets will ultimately have a strong influence on determining how many conservation areas are needed in a planning region and the extent of area within the region that they will occupy.

Setting meaningful and realistic conservation goals for targets is challenging. There is no scientific consensus on how many populations are needed or how large these populations need to be for conservation of target species (Beissinger and Westphal 1998), although most scientists suggest that a minimal level of redundancy is essential for long-term viability (Shaffer and Stein 2000). For communities and ecosystems, there is little empirical or theoretical research that addresses how best to represent these targets in a system of conservation areas. Finally, in many cases there will be tradeoffs in goals related to the need to conserve multiple examples of targets, on the one hand, while, on the other hand, conserving areas of sufficient quality (see step 5) to persist over the long term.

Conservation goals should have two components: a representation component that refers to the number of occurrences or percentage of each target that should be represented within conservation areas, along with some indication of how those targets should be distributed or stratified across a planning region; and a quality component that addresses the level of viability or ecological integrity thought necessary for these targets to persist over the long term. For example, most marine studies have suggested that ecologically functional reserves will need to cover at least 20% of a planning region if the biodiversity of that region is to be fully conserved. Broader goals have been suggested for marine reserves when an additional goal is to sustain fisheries (see Roberts and Hawkins 2000). Beyond these two components, additional criteria, such as the rangewide distribution of the target relative to the planning region, can be considered in goal setting. For example, if a particular target is endemic to or largely restricted to a planning region, then goals may be set correspondingly higher than for a target that is more widely distributed across several planning regions (Anderson et al. 1999).

Planners also need to ensure that conservation targets are, to the extent possible, distributed across the environmental gradients in which they occur. Doing so helps safeguard against natural catastrophes (storms, disease) that could eliminate targeted features occurring in relative proximity to each other and helps conserve the genetic and ecological variation that occurs in target species and communities across their range. Most ecoregional classifications are hierarchical and have already been divided into subunits based on differences in physical factors (Bailey 1998, Zacharias and Howes 1998). These subunits can be useful for stratifying the distribution of terrestrial conservation targets across the region or ecoregion. In freshwater ecosystems, the level of the classification identified as an ecological drainage unit (figure 3) can serve as a useful stratification unit for conserving aquatic conservation targets across their range of distribution.

Because of the scientific uncertainty involved in setting goals and the need for alternative solutions in most planning processes, biologists and planners should consider setting a range of numeric goals for targets (Jennings 2000). For example, in the Cape Floristic region of South Africa, planners established three goals—10%, 25%, and 50% of the original extent of each vegetation type within the planning area—and then examined alternative portfolios of conservation areas (see step 6) that corresponded to these different goals (Heijnis et al. 1999).

Step 4: Assess existing conservation areas for their biodiversity values

A logical early step in any planning process for conserving biodiversity is to determine what biological features are already under adequate management within existing conservation areas (Margules and Pressey 2000). The biota of many of the world's parks, refuges, wilderness areas, marine protected areas, and nature reserves have been poorly inventoried, in part because of the perception that these areas are already "protected" and that survey funds would be better spent on areas yet to be designated for conservation management. Nevertheless, interviews with resource experts for these protected areas often reveal considerable information on the status and distribution of biodiversity and the need to devote greater management attention to the conservation of this diversity. Remote-sensing imagery of vegetation cover for these areas can also be useful in assessing the status and distribution of community and ecosystem-level targets. Given the limited dollars available for new conservation areas, it is especially important to determine which conservation targets are already within existing conservation areas and the degree to which these areas are being appropriately managed for these targets. The final step in this framework, identifying priority conservation areas (step 7), will use this information as one of the criteria for setting priorities.

The Department of the Interior established the National Gap Analysis Program to undertake the assessment of the degree to which existing conservation areas adequately represent native vertebrate species, threatened and endangered species, and vegetation cover types (Jennings 2000). Irrespective of land ownership, gap programs typically assign a biodiversity management category ranging from 1 to 4 to each conservation area, with status 1 referring to those areas with permanent protection of natural land cover from conversion to status 4, where there is no legal mandate to prevent conversion of natural habitats. Those conservation targets found in status 1 and 2 lands are usually regarded as being under adequate conservation management (*Gap Analysis Handbook,* available at *www.gap.uidaho.edu/handbook).* The World Conservation Union (1994) uses a somewhat similar though more restrictive approach to classify the world's legally declared protected areas, with six categories ranging from category I (strict nature reserve and wilderness areas) to category VI (areas managed primarily for the sustainable use of natural resources).

Step 5: Evaluate the ability of conservation targets to persist

Conservation planners have devoted considerable resources to representing the elements of biodiversity within a system of conservation areas, but traditionally have paid only scant attention to the factors responsible for the long-term persistence of conservation targets (Balmford et al. 1998, Margules and Pressey 2000). For species, this often means using population viability analyses to assess whether populations can persist over some specified time period (Beissinger and Westphal 1998), an approach largely restricted to a small group of species in the developed world for which data are relatively plentiful. For communities or ecosystems, it means assessing whether disturbance regimes are intact and areas are sufficient in size to ensure survival and recolonization from natural or human-caused disturbances (Poiani et al. 2000).

One practical approach for evaluating the ability of species, community, and ecosystem-level targets to persist is to use a qualitative ranking system that employs three criteria: size, condition, and landscape context (Anderson et al. 1999, Groves et al. 2000, Stein and Davis 2000).

Size is a measure of the area or abundance of a conservation target's occurrence. At the species level, size takes into account the area of occupancy and the number of individuals. For communities or ecosystems, size relates to the area needed to ensure survival from large-scale natural disturbances; it has been referred to as the minimum dynamic area (Pickett and Thompson 1978). Planning teams from TNC use both the concept of minimum dynamic area and the area requirements of wide-ranging species to assess the size criterion for community and ecosystem-level targets (figure 5).

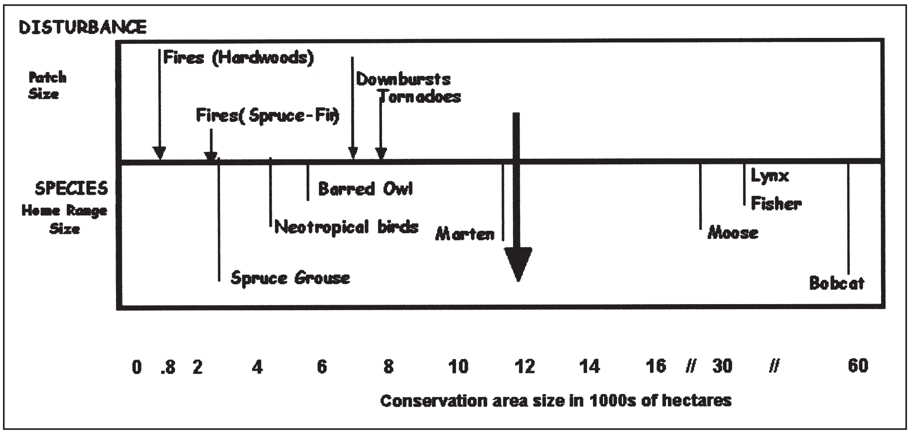

Figure 5. Factors used to assess the adequacy of size for proposed conservation areas of forested ecosystems in the Northern Appalachians Ecoregion. Two principal factors can be used to assess size: the home range of wide-ranging animal species or historical patch sizes from natural disturbances. In this figure, disturbance is defined as four times the patch size of the most severely disturbed patch, based on historic data suggesting that about 25% of any given forested area of New England is expected to be severely disturbed at any one time. The home range estimate is based on the area needed to accommodate a viable population of each species. In the Northern Appalachians Ecoregional Plan, the minimum size for forested conservation areas (large vertical down arrow) was set at approximately 12,000 hectares. From Anderson (1999).

Condition is an integrated measure of the composition, structure, and biotic interactions that characterize the occurrence of a conservation target. For example, this factor would include information on the reproduction and age structure of a population, the canopy or understory structure of a community, or any of several biotic interactions such as predation and disease. In assessing condition, it is often helpful to examine the extent of anthropogenic impacts (e.g., habitat fragmentation and degradation, introduction of exotic species) and the presence or absence of biological legacies—critical features of communities and ecosystems that take generations to develop (e.g., fallen logs and rotting wood in old-growth forests).

Landscape context is an integrated measure of two factors: intactness of dominant ecological processes that help maintain conservation targets (e.g., natural hydrological flow and fire regimes) and connectivity, which allows species to disperse, migrate, and otherwise move to adjacent habitats to meet life cycle needs.

In practice, planners have often found it adequate for their purposes to rate each occurrence of a conservation target, for each of these three criteria, as "very good," "good," "fair," or "poor." Occurrences of those targets that receive an overall fair or poor rating are generally excluded from further consideration in the planning process. Details on the use of this rating scheme and examples of its application are provided by Groves and colleagues (2000). Because of the paucity of information on minimum dynamic areas and disturbance regimes for many communities and ecosystems, much work remains to make these criteria more operational for conservation targets above the species level.

Time and funding, coupled with limited information, usually precludes an evaluation of each of these criteria for all occurrences of conservation targets. One shortcut is to combine various sorts of digitally available information to use as an index of the suitability of a site or area for conservation purposes. Davis and colleagues (1996) used GIS to combine information on road density, human population density, percentage of remaining natural land cover, distance to existing conservation lands, integrity of aquatic systems, and percentage of land in private ownership into a "suitability index" for a biodiversity assessment in the Sierra Nevada Ecoregion. This index, which has now been used in several TNC ecoregional conservation projects, effectively steers planners away from areas with high human use and conversion of natural land cover on the assumption that these areas will be more expensive to manage and that conservation targets in these areas will very likely have lower probabilities of persistence. In freshwater and marine ecosystems, TNC and other regional conservation planning projects have used similar GIS-based suitability indices that aggregate a number of physical and biological criteria (e.g., road density, number of dams, land use and land cover data, percentage of modified shoreline, and point sources of pollution) into an overall "integrity" value (Moyle and Randall 1998, Groves et al. 2000).

Step 6: Assemble a portfolio of conservation areas

Following the collection and mapping of data on conservation targets and assessment of the conditions for persistence, conservation planners can identify a set of potential conservation areas, including areas that do not have acceptable levels of viability and integrity but which may be restored in the future. In most situations, planning teams will have a substantial amount of information on conservation targets, ratings of persistence or suitability, land ownership and management, and other ancillary data sets. Because of the relative complexity of the task, there are a number of advantages to using computerized algorithms with GIS as a tool to aid the identification of conservation areas (figure 6). An algorithm is a step-by-step problem-solving procedure, usually a computational process defined by stipulations written into a computer program. In the case of biodiversity conservation, a common challenge is to select the set of conservation areas that best meets the target-based goals of the project within the smallest area. Fortunately for conservation planners, many such algorithms have been developed; several of them can be accessed for free on the Internet (see Williams 1998 for a review of algorithms for area selection).

The primary advantage of using algorithms is that they allow planners to delineate explicit "rules" to identify a set of conservation areas and to assess alternative portfolios of conservation areas by making changes in these rules. For example, a team might choose to examine a portfolio of conservation areas that is located mostly on public lands versus one that emphasizes private lands. Other teams may find it desirable to design a portfolio of conservation areas with a minimum size requirement for each area. A recent biodiversity plan for Papua New Guinea (Nix et al. 2000) demonstrated how algorithms can be used to integrate economic tradeoffs into the selection of conservation areas or to eliminate certain areas (e.g., highly altered lands) within the planning region from consideration.

Staff members or partner organizations that undertake conservation action or management for particular conservation areas need to be involved in the application of algorithms designed to select these areas. In Australia, interactive algorithms for area selection have been used to negotiate settlements between timber companies and conservationists regarding the use of public lands (Pressey 1998). Experiences in TNC's ecoregional planning efforts suggest that managers and conservation practitioners who do not understand the algorithms or why a particular place has been identified for conservation will be less supportive of a regional conservation plan than they otherwise might be (Groves et al. 2000).

The final task in assembling a portfolio of conservation areas is consideration of the overall configuration or design of the portfolio. Several design principles for a network of conservation areas have emerged from biogeographic theory and landscape ecology (Noss et al. 1997). Collectively, these principles lead to an emphasis on selecting landscape-scale conservation areas. Typically, these areas contain larger, more viable occurrences of conservation targets and are more likely to be sustained by intact, functional ecological processes (Soulé and Terborgh 1999).

Decisions concerning the overall design or configuration of a network of conservation areas must balance the desirability of securing new conservation areas and enlarging existing ones with the need to consider proximity and connectivity among these areas. In practice, this has

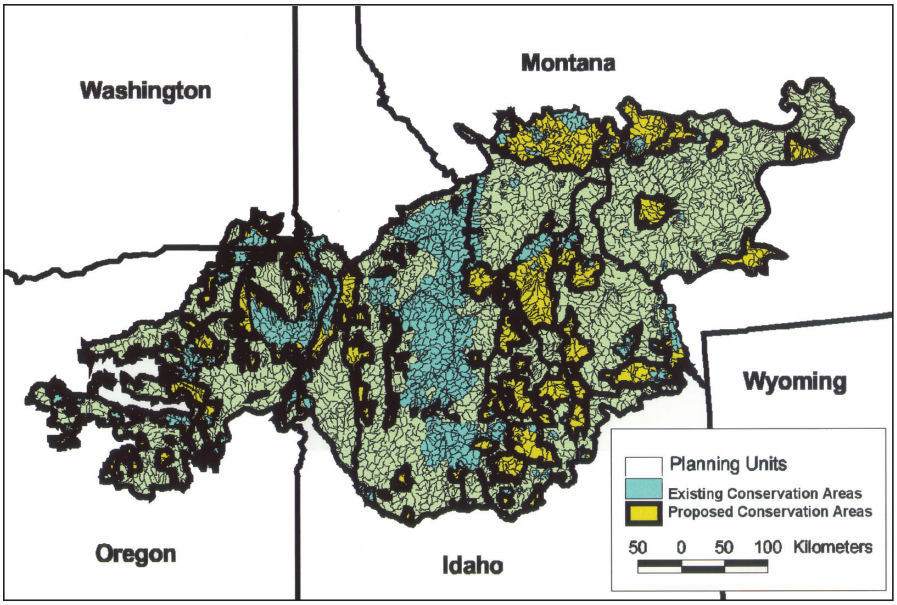

Figure 6. Portfolio of conservation areas for the Middle Rockies–Blue Mountains Ecoregion. Conservation areas are roughly delineated along the boundaries of watersheds referred to as HUCs (hydrological unit codes). HUCs make excellent base map units for organizing a variety of biological, socioeconomic, and environmental data and can serve as a generalized selection unit for conservation areas. HUCs are available digitally from the US Environmental Protection Agency at a variety of spatial scales. From Middle Rockies–Blue Mountains Planning Team (2000).

proven both difficult and contentious. It is difficult because there is often little biological information to guide the design of connectivity. It is contentious because there are convincing arguments in favor of establishing linkages among conservation areas (Beier and Noss 1998), but there is also compelling evidence that the configuration of conservation areas is not nearly as important to species survival as preventing overall habitat losses (Fahrig 2001).

Step 7: Identify priority conservation areas

Experience in TNC ecoregional planning projects indicates that most plans will identify over 100 potential conservation areas. Some of these areas are in urgent need of conservation action, while others are not. Therefore, a final step in this planning framework is to set priorities for action among the portfolio of potential conservation areas. Our planning framework uses five criteria for setting these priorities: degree of existing protection, conservation value, threat, feasibility, and leverage (Groves et al. 2000).

"Degree of protection" refers to how well or the extent to which conservation targets are already represented within the existing set of conservation areas in an ecoregion (step 4). Higher priority is given to areas with targets that are not already well represented. The conservation value of an area is based on the number of conservation targets, the diversity of these targets (e.g., terrestrial and aquatic), and their predicted ability to persist over the long term. Areas with more conservation targets (step 1) and higher persistence or suitability ratings (step 5) are assigned a higher priority. Conservation areas that face critical threats are assigned a higher priority than those that are not imperiled; the greater the degree of threat, the higher the priority. Feasibility refers to an organization's capacity to gain protection for an area (through land acquisition, for example) and to secure sufficient funding, staff, and strategies to abate critical threats. Finally, leverage is the ability to take conservation action at one area and thereby effect conservation action at other areas. In practice, a qualitative rank of high, medium, or low is assigned for each criterion (see Groves et al. 2000 for definitions of qualitative ranks) for each potential conservation area. These criteria rankings are summed for the conservation areas, each of which is assigned an overall priority rank. As with any qualitative ranking scheme, results should be used in setting priorities in conjunction with the sound judgment and personal knowledge of conservation areas by members of the planning team and other experts.

Approaches to regional conservation planning

Several scientists have advanced principles, characteristics, and criteria for the development of biodiversity conservation plans. For example, Shaffer and Stein (2000) outlined three principles for successful conservation of biodiversity that they termed representation, resilience, and redundancy. *Representation* in its simplest form means "saving some of everything"—ensuring that all species and communities native to a region can be found, to the greatest extent possible, within lands and waters that are primarily managed for conservation purposes (step 1). *Resilience* refers to ensuring that these species and communities can persist and evolve for long periods of time (step 5). *Redundancy* admonishes conservation practitioners to refrain from placing all of their eggs in one basket, thereby hedging bets of failure of any single population of a species or occurrence of a community to survive (step 3). Our framework is entirely consistent with these principles.

Margules and Pressey (2000) outlined a six-stage framework for systematic conservation planning. Shafer (1999) developed a similar set of steps for reserve planning in national parks. Their stages included identifying which biotic and abiotic features can serve as surrogates for biodiversity in the planning region and gathering information on these features (steps 1 and 2); setting explicit goals for these features, including goals for ecological processes (steps 3 and 5); assessing existing conservation areas for their representation of these features (step 4); selecting new conservation areas (step 6); implementing conservation action according to priority level (step 7); and effectively managing and monitoring conservation areas. With the exception of this final stage regarding the management of conservation areas, which we earlier suggested is best accomplished through a separate site or project planning process, the seven-step framework incorporates and is consistent with these stages.

Soulé and Terborgh (1999) outlined a scientific program for conserving nature in North America. The rationale for this program, the Wildlands Project, centers on the idea that networks of large and well-connected protected areas (referred to as core areas or wildlands) require keystone species, especially large carnivores, to stabilize prey populations and maintain ecological diversity. Core areas are selected on the basis of three criteria or types of conservation targets (Noss et al. 1999): representation, special elements, and focal species. Representation refers to conserving intact examples of each vegetation or habitat type (defined as target ecosystems in step 1) across the environmental gradients in which they occur. Special elements are rare species and communities, pristine sites (e.g., roadless areas), and other features unique to a region (e.g., artesian springs, mineral licks, indigenous sacred sites) that are thought to have high conservation value. Finally, focal species are conservation targets whose needs define answers to two questions: How large do conservation areas need to be, and what should their configuration be?

With the exception of some special elements, the three types of conservation targets used by Noss and colleagues (1999) are consistent with those identified in step 1. We elected to not include such features as mineral licks, springs, caves, and roadless areas as a type of conservation target, unless they had identifiable biotic targets associated with them or were part of an environmental or physically derived classification system.

In practice, the Wildlands Project has emphasized wide-ranging carnivores as targets and connectivity between core areas to a greater extent than TNC ecoregional projects, whereas TNC projects have placed greater emphasis on using a more comprehensive set of conservation targets at a variety of spatial scales to select conservation areas. Both steps are important aspects of conservation planning, and TNC's ecoregional projects are now moving to better incorporate wide-ranging species and network design, and the Wildlands Project is seeking to bring greater consistency to its conservation planning methods across projects (Barbara Dugelby, [The Wildlands Project, Blanco, Texas], personal communication, September 2000).

Conclusions

As the list of endangered species grows longer, it is clear that additional strategies and approaches are needed to conserve biological diversity. Because habitat loss and degradation are the leading causes of imperilment for most species (Wilcove et al. 1998, Hilton-Taylor 2000), it is equally clear that more lands and waters need to come under conservation management if future losses are to be prevented. We have outlined a framework for identifying the most important remaining areas for conservation and restoration. The seven-step framework is based upon scientific principles and theories that represent a synthesis of thinking from population biology, community ecology, and landscape ecology. Although the methodology for the framework differs from some other regional planning approaches, there are more similarities than differences. A consensus is emerging on the most important elements of planning for the express purpose of conserving biological diversity. Some of the underpinnings of the seven steps rest on assumptions that remain inadequately tested (e.g., surrogate measures for biodiversity) and methods that are not yet fully developed (e.g., assessing persistence of conservation targets). Nevertheless, the urgency of the conservation mission demands that conservation plans based on the best available scientific information and methods be implemented now, while explicitly acknowledging their limitations and working toward their improvement..

This seven-step approach to conservation planning, which has been applied to terrestrial, freshwater, and marine environments, offers numerous benefits. First, it allows conservation planners to set goals that are based on assessments of the biological needs of species, communities, and ecosystems, not on arbitrary, subjective estimates of how much land a society can set aside in protected areas (Soulé and Sanjayan 1998). Second, this framework complements single-species conservation approaches by incorporating a broad set of conservation targets at a variety of levels of biological organization and spatial scales. Third, at a median cost of $234,000 per plan ($n$ = 24 plans, staff salary, and all operating costs included) and an average completion time of just less than 2 years, application of the framework strikes a reasonable balance between planning and action. Fourth, the framework provides an explicit means for conservation planners to measure whether the set of conservation areas that they have identified will sufficiently represent the biodiversity of the region and achieve the target-based goals of the plan. Fifth, the proposed framework pays due diligence to a long-overlooked aspect of conserving biodiversity: the underlying ecological processes and functions that support the long-term persistence of biodiversity. Finally, by using an approach that represents biodiversity in a set of conservation areas across environmental regimes in which targeted features are known to occur, the framework may help conserve biodiversity in the face of global climate change (Halpin 1998).

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