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BEYOND PROTECTED AREAS

DEFINING A NEW GEOGRAPHY FOR BIODIVERSITY CONSERVATION

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INTRODUCTION

The primary approach to conserving biodiversity in a world of human use involves *protected areas*, locations where human activity is limited in some way to help conserve natural or cultural resources. The roughly 13% of the earth's terrestrial surface currently under some sort of protection has contributed enormously to the maintenance of biological diversity (LeSaout et al. 2013). Unfortunately, relying entirely on protected areas to conserve biodiversity has inherent problems. For several reasons, protected area effectiveness can vary greatly—at one extreme successfully limiting direct and indirect human impact on the plants, animals, and habitat they contain, while at the other extreme providing so little protection that conditions within their bounds are virtually indistinguishable from conditions beyond. Moreover, reliance on protected areas for conservation often yields a landscape of isolated islands of natural habitat amid broad tracts converted for human use, compromising the long-term potential of these areas to support ecological processes necessary to maintain many species. Although well-designed and well-managed protected areas have been extremely important to biodiversity conservation, the combination of continuing high rates of species loss and growing human impacts suggests a need to think beyond this model to one that improves species survival and ecosystem maintenance.

The following chapter explores the conservation of biological diversity in the twenty-first century, focusing in particular on the need to expand beyond protected areas and some necessary considerations in pursuing this task. It begins by presenting the current state of biodiversity and its conservation, including the task of monitoring the status of various plant and animal species, the definition of geographic priorities for conservation efforts, and the use of protected areas as a strategy for maintaining nature. The chapter then examines the potential for extending conservation beyond protected areas through developing corridors that link reserves as well as accommodate resident biodiversity. It discusses potential shortcomings of corridors as implemented, exploring considerations for creating connections that provide greater potential for reestablishing connectivity while reducing needs for systematic management. The chapter closes with a plea for strategically designing and locating mixed-use landscapes that maintain certain types of habitat, create networks of connectivity to reduce ecological isolation, and minimize adverse impacts on local people in settings that support a range of non-human species as well.

THE STATE OF BIODIVERSITY CONSERVATION

Biodiversity can be defined generally as the diversity of life, measured at a variety of levels that include genes, species, and ecosystems (Gaston and Spicer 2004). This chapter focuses on species, the most closely monitored indicator of biodiversity. Currently, biologists have identified between 1.5 and 1.75 million species on Earth, a small fraction of the 6 to 15 million species felt to inhabit our planet (Pimm et al. 2008). Estimated rates of extinction for the recent past and near future vary by taxon, though biologists propose an overall current extinction rate at 1,000 times or more greater than historic background rates (Pimm et al. 1995, 2008; Pereira et al. 2010), reminiscent of the five great prehistoric mass extinctions that eradicated much of the biological diversity that existed at various times in the past (Raup and Sepkoski 1982). Recent studies reveal that several key components of the biological world are under duress (Purvis et al. 2000; Stuart et al. 2004; Pimm and Jenkins 2005; Butchart et al. 2010; Hoffmann et al. 2010; Jenkins et al. 2013; Pimm et al. 2014). Researchers offer several different reasons for this biodiversity loss (Wood et al. 2000; Baillie et al. 2004), the leading cause being habitat destruction (Pimm and Raven 2000; Laurence 2010).

The most systematically monitored type of habitat is forest, assessed every decade by the UN Food and Agriculture Organization (FAO). The most recent assessment estimated 130,000 km^2 of forest loss annually between 2000 and 2010, reduced from the 160,000 km^2 per year during the 1990s but still alarmingly high (FAO 2010). Other causes contribute in varying degrees to the decline in biodiversity, including overexploitation, invasive species, disease, environmental contaminants, incidental mortality, and climate change, among others (Baillie et al. 2004). One can trace all of these causes of biodiversity decline directly or indirectly to people. For example, agriculture is the leading cause of natural habitat destruction globally (fig. 2.1; Laurence 2010), covering much of our planet's surface and expanding rapidly to meet an increased human demand for food projected to double between about 2010 and 2050 (Foley 2011).

The crisis in global biodiversity loss underway in the early twenty-first century ultimately is due to the enormous human population on our planet. As this chapter goes to press, more than 7.3 billion people live on Earth, with another billion expected to be added in the next 12 years (United Nations, Department of Economic and Social Affairs [UNDESA] 2013)—a consequence of growth in excess of 225,000 per day (Gorenflo 2006). The most recent global population projections prepared by the United Nations predict a total of 8.1 billion by 2025 and 9.6 billion by 2050, using a medium fertility estimate (UNDESA 2013). Most of the population growth is expected to occur in developing countries, alone projected to total 8.2 billion by 2050. More than half of the projected population growth is anticipated to occur in a few nations—Nigeria, India, Tanzania, the Democratic Republic of Congo, Niger, Uganda, Ethiopia, and the United States. All but the last of these countries lie in the tropics, largely consistent with the current geographic distribution of humans (fig. 2.2). Such population growth, amounting to an additional 33% in the global total by 2050, will generate considerable increase in demand, affecting the countries that host the demographic increase as well as other nations that provide resources to help support it.

The most broadly endorsed program to assess and monitor the state of biological diversity on Earth is the International Union for the Conservation of Nature (IUCN) *Red List* (Baillie et al. 2004). Prepared in collaboration with other organizations—including BirdLife International; Conservation International; NatureServe; the Royal Botanic Gardens, Kew; and the Zoological Society of London—the IUCN Red List is a constantly updated assessment of the status of species, the most recent evaluations found on a frequently updated website at http://www.iucnredlist.org. The aim of the Red List is to compile accurate information on the conservation status of the world's species, providing a foundation

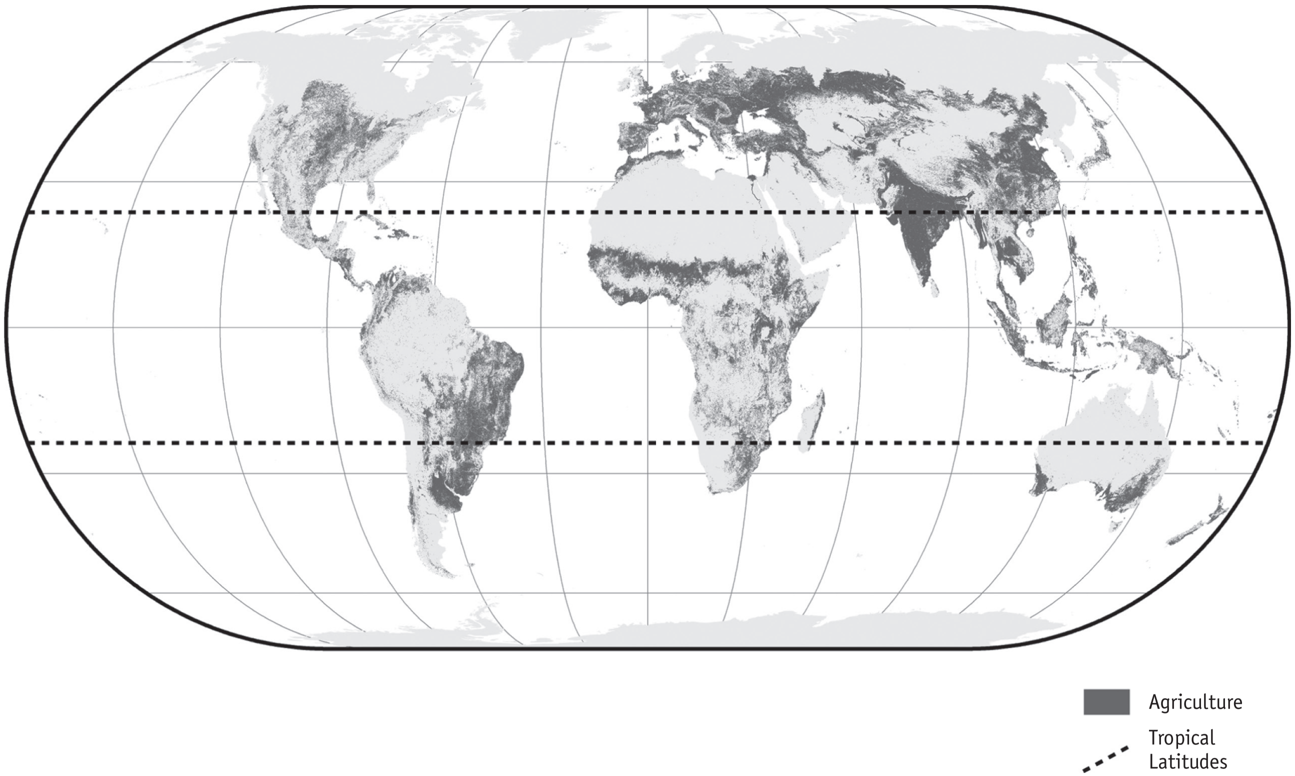

Figure 2.1 Extent of agriculture in 2009.
(*Source*: 2009 data from European Space Agency 2010; projection: Eckert IV.)

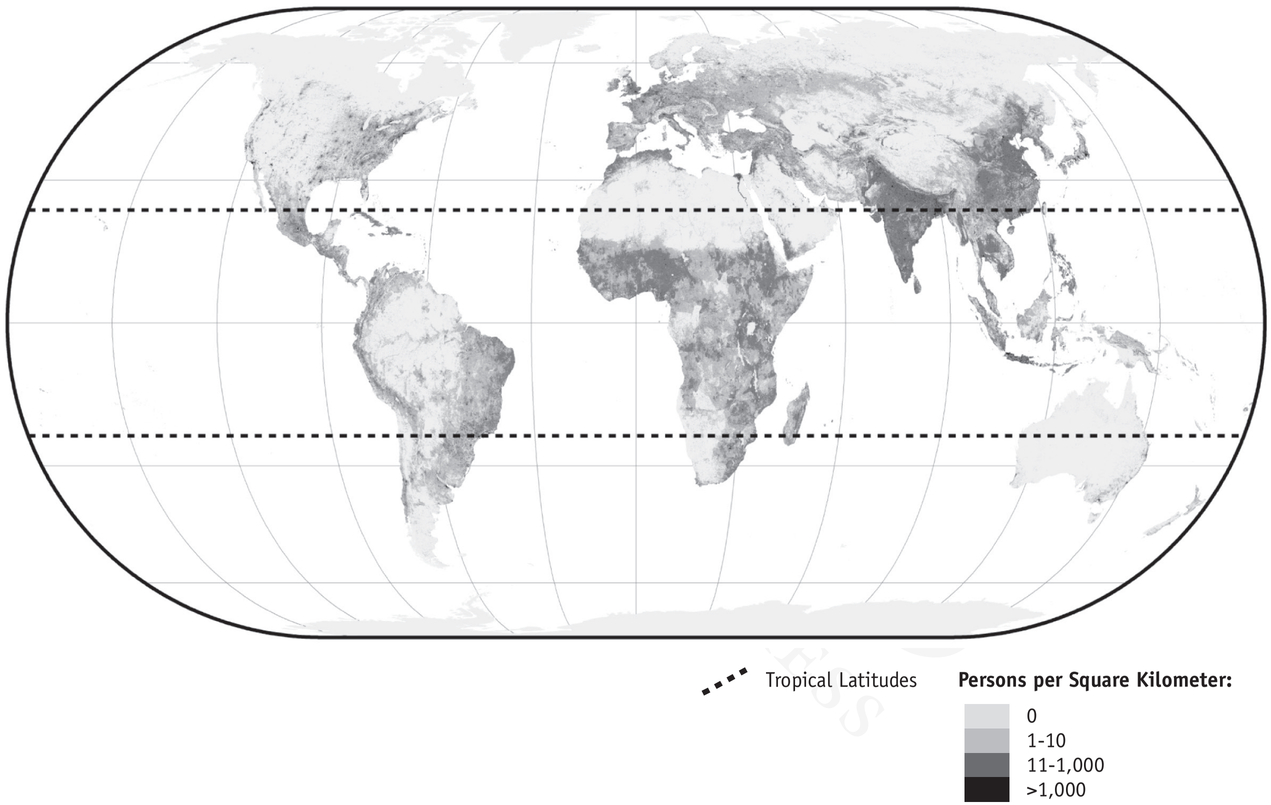

Figure 2.2 Population in 2010.
(*Source*: Data from Bright et al. 2011; projection: Eckert IV.)

for conservation efforts to maintain these species (Rodrigues et al. 2006). Currently, IUCN uses nine levels of endangerment to categorize species (IUCN 2012): Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient, and Not Evaluated. The Red List is not comprehensive, focusing on species with the greatest risk of extinction. Criteria used to determine if a species is threatened—that is, Critically Endangered, Endangered, or Vulnerable—are population reduction over time, geographic range of occurrence, small population and continuing decline, very small populations or restricted populations, and quantitative analysis of extinction probability (Baillie et al. 2004). Updates of the Red List continue to increase the number of species whose conservation status is known; unfortunately, the number of threatened species continues to increase as well. As of 2013, the IUCN Red List contained more than 37,000 species, with nearly 7,400 listed as globally threatened with extinction (IUCN 2014). Efforts by the Commission of Ecosystem Management (CEM) of IUCN have recently established a Red List for Ecosystems, acknowledging that the conservation status of species often is symptomatic of broader ecological problems (CEM-IUCN 2014). This program uses criteria to assign levels of threat analogous to those used for species, providing a more complete basis for assessing conservation status along with information on how to address it.

Biodiversity is arranged unevenly across Earth, as are threats to that biodiversity. The majority of several taxa occur in tropical locations (Jenkins et al. 2013; fig. 2.3). In response to the uneven geographic distributions of species, conservationists have developed different schemes to prioritize their efforts: Biodiversity Hotspots, Centers of Plant Diversity, Crisis Ecoregions, Endemic Bird Areas, Frontier Forests, Global 200 Ecoregions, High Biodiversity Wilderness Areas, Last of the Wild, and Megadiversity Countries (Brooks et al. 2006). All of these prioritization templates consider some assessment of irreplaceability, vulnerability, or both. Irreplaceability measures conservation opportunities, placing particular importance on, for instance, species unique to a particular area or habitat that is globally rare. Vulnerability measures likelihood that a conservation target will be lost, assessed in terms of variables associated with the natural and human environment. The prioritization schemes apply these criteria in different manners; although they define different parts of the planet as areas of focus, regions in the tropics are particularly well represented, in many cases showing high co-occurrence for multiple templates (Brooks et al. 2006).

Although prioritization schemes vary, approaches to conservation both within regions deemed essential for maintaining biodiversity and elsewhere often involve protected areas. Protected areas are designated localities created and managed to achieve long-term conservation of natural phenomena, associated ecosystem services, and cultural values (IUCN 1994). Protected areas occur on land, in freshwater, and in marine settings, in some cases involving more than one type of geographic area and covering a broad range of natural and cultural settings (Chape et al. 2005). Reserves vary in many ways—national parks, for instance, often differ fundamentally from community forests in their design, management, and conservation effectiveness. One means of distinguishing among protected areas is via their intended purpose, as embodied by the IUCN categorization according to management objectives (IUCN 1994; table 2.1). Protected area types range from those managed explicitly for the conservation of nature (protected area type Ia) to those managed for the sustainable use of natural resources (type VI). In some cases, single protected areas incorporate multiple management objectives—the *biosphere reserve* being the best-known multi-management model, where a core is maintained for strict biodiversity conservation, a buffer surrounding the core enables conservation research, tourism, and recreation, and an outer transition zone accommodates human settlement and resource use (United Nations Educational, Scientific, and Cultural Organization/Man and the Biosphere Secretariat [UNESCO/MAB] 2002).

In addition to varying management objectives, realization of these objectives varies considerably among protected areas as well (Bruner et al. 2001; Joppa et al. 2008; Joppa and Pfaff 2010). Frequent weaknesses encountered in management planning, monitoring and evaluation of management effectiveness, budget, and law enforcement often emerge to undermine protection (Carey et al. 2000; Dudley

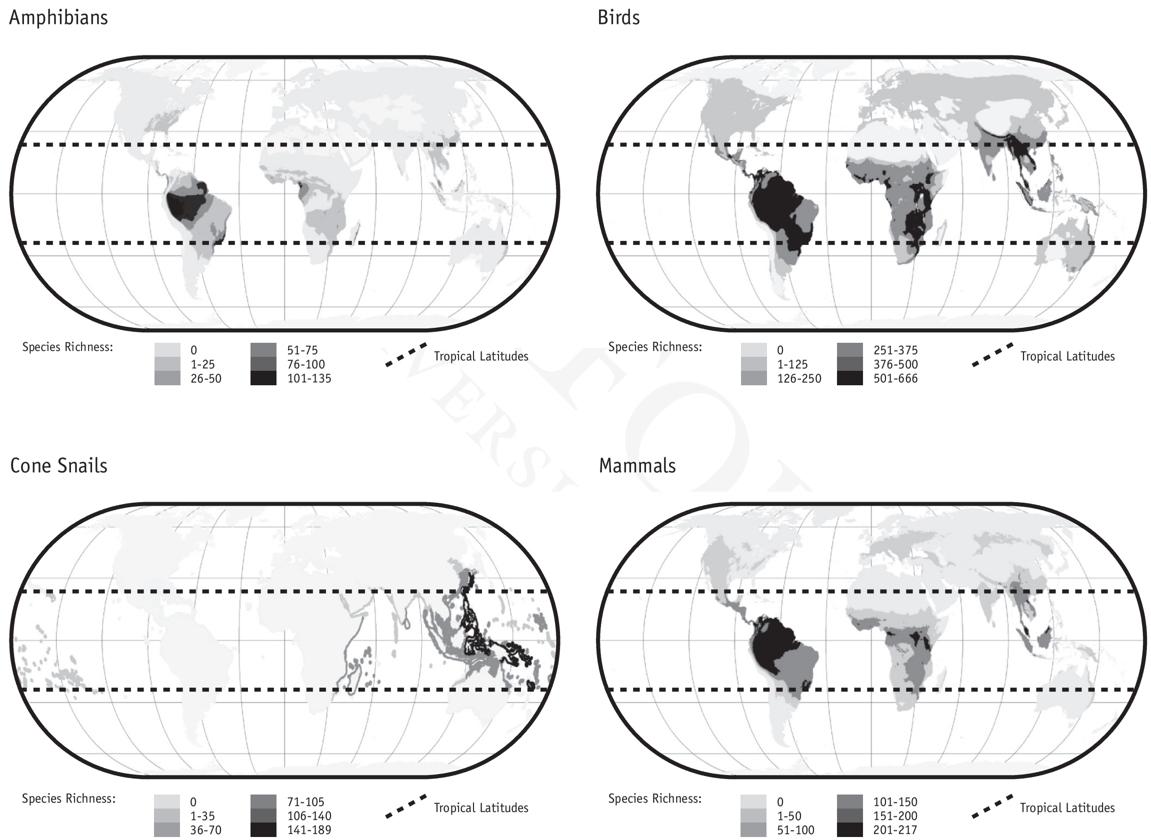

Figure 2.3 Selected priority regions for biodiversity conservation.
(*Source*: Data from Biodiversitymapping.org 2014; projection for all maps: Eckert IV.)

Table 2.1 IUCN protected area management categories

Category	Reserve Type	Management Emphasis
Ia	Strict nature reserve	Protected area managed primarily for scientific reasons; area containing important ecosystems, geological features, physical features, or species important for scientific research or environmental monitoring, and managed to enable such inquiries
Ib	Wilderness area	Protected area managed primarily for wilderness protection; large area of land or sea slightly modified from natural state, with little or no human habitation, managed to maintain natural condition and processes
II	National park	Protected area managed primarily for recreation and ecosystem protection; natural area managed to protect one or more ecosystems, exclude human settlement or exploitation, and provide a foundation for recreational, educational, cultural, spiritual, and visitor opportunities
III	National monument	Protected area managed primarily for conservation of specific natural features; area managed to help protect natural or cultural features of outstanding value due to rarity, representativeness, aesthetic value, or cultural importance
IV	Habitat or species management area	Protected area managed primarily for conservation; area of land or sea managed to maintain habitat or characteristics necessary for one or more particular species
V	Protected landscape or seascape	Protected area managed primarily for conservation of landscape or seascape and for recreation; area of noteworthy ecological, aesthetic, or cultural value, often with high biological diversity, resulting from human-environment interaction that is managed to maintain that interaction and the characteristics it produced
VI	Managed resource protected area	Protected area managed primarily for sustainable ecosystem use; area of mainly natural systems managed to maintain those systems while allowing continued resource use to meet the needs of human communities that rely on them

Source: Dudley 2008.

et al. 2004; Leverington et al. 2010). Protected area effectiveness is becoming a major concern, as conservation increasingly relies on reserves to maintain biological diversity and conservationists widely recognize that simply establishing a protected area does not guarantee biodiversity conservation. For example, a recent performance assessment of roughly 8,000 reserves revealed that about 40% show major deficiencies (Leverington et al. 2010).

Consistent with the main cause of biodiversity loss, a major problem with ineffective protected areas is their failure to maintain habitat (Dudley et al. 2004; Leverington et al. 2010). Although several biomes are important to conservation globally (Laurence 2010), including grasslands, deserts, wetlands, and marine settings, forests (tropical, subtropical, temperate, and boreal) are the easiest to monitor broadly because their extent is readily visible with several types of satellite imagery. Studies that compare deforestation within protected areas to deforestation outside those same areas indicate that protection tends to reduce forest loss (Cornell

2000; Bruner et al. 2001, 2004; Sanchez-Azofeifa 2003; Oliveira et al. 2007). Indeed, a review of 36 protected areas indicated that 32 experienced lower deforestation within their boundaries than surrounding areas (Naughton-Treves et al. 2005). Comparisons between deforestation inside protected areas to unprotected localities that are similar (though not adjacent) support this conclusion, though indicate that estimates of protected area effectiveness using comparisons with tracts immediately outside their boundaries overestimate the effectiveness of reserves (Mas 2005; Andam et al. 2008). Unfortunately, in many cases protected areas fail to maintain forest. A study of nearly 200 protected areas over a two-decade period beginning in the early 1980s revealed that roughly 25% experienced deforestation within their boundaries (DeFries et al. 2005). In other instances, logging and wood harvesting continue within reserves despite their protected status (Curran et al. 2004), a pattern documented broadly and in many instances legal (Dudley et al. 2004; Leverington et al. 2010). Measuring the effectiveness of protected areas in stemming the loss of forest habitat is complicated by additional variables that often play a key role in deforestation, such as access (Chomitz and Grey 1996; Cropper et al. 2001; Deininger and Minten 2002; Gorenflo et al. 2011), though results ultimately are inconclusive—some reserves work well, others less so.

Regardless of their degree of success in maintaining habitat, forested or otherwise, protected areas also can fail to conserve biodiversity within their bounds (Leverington et al. 2010; table 2.2).

Table 2.2 Top 20 threats to protected areas and frequency encountered

Threat	**Frequency Encountered (%)**[a]
Hunting, killing, and collecting terrestrial animals in protected area	79
Logging and wood harvesting	61
Livestock farming and grazing within protected area	57
Recreational activities	47
Annual and perennial non-timber crops within protected area	45
Fire and fire suppression	44
Fishing, killing, and harvesting aquatic resources	43
Housing and settlement within protected area	43
Gathering terrestrial plants or plant products (non-timber)	42
Mining and quarrying	40
Dams and water management/use	38
Roads and railroads	36
Other ecosystem modifications	31
Human impacts, unspecified	25
Invasive species, unspecified	25
Tourism and recreation infrastructure within protected area	25
Agricultural and forestry effluents	20
Garbage and solid waste	20
Household sewage and urban waste water	18
Industrial and military effluents	18

Source: Leverington et al. 2010.

[a] Based on examining a sample of 227 protected areas.

One of the most frequently encountered reasons is illegal hunting and fishing, which can yield reserves that appear to be healthy but have reduced populations of many animals previously present (Oates 1999; Redford and Feinsinger 2003; Dudley et al. 2004; Stoner et al. 2007; Wittemeyer et al. 2008; Leverington et al. 2010). Illegal hunting and fishing often are undertaken to provide food for local people, though killing animals for particular resources (e.g., ivory) also occurs (Carey et al. 2000). Animals also are harvested by trapping to supply the wildlife and fish trade. Logging, extracting fuel wood, and harvesting non-timber forest products serve to remove valuable plant species and degrade protected area ecosystems (Dudley et al. 2004). Encroachment by agriculture, ranches, and urban development both destroy habitat within protected areas and isolate them further from other natural habitat (Dudley et al. 2004; DeFries et al. 2005). Grazing similarly often encroaches on protected areas, occasionally occurring within their boundaries and with impacts broadly similar to those caused by agricultural encroachment (Leverington et al. 2010). Extraction of mineral resources, and the contamination that often accompanies such activities, serve to undermine the conservation success of protected areas (van Schaik et al. 1997; Nolte et al. 2010). Other forms of pollution, including that from nearby settlements, degrade the protection afforded by reserves (Carey et al. 2000). Fire occurs both naturally and through introduction, either purposefully or accidentally in protected areas, the frequency and extent often degrading both habitat and the species that rely upon it.

Reliance on protected areas to conserve biological diversity is, in many ways, a logical solution. In a world where biodiversity is under pressure virtually everywhere, establishing localities which restrict certain activities that could adversely affect nonhuman species makes considerable sense. However, in relying heavily on protected areas, conservationists are depending on a single solution, in essence placing all their eggs in one basket. When a protected area does not function adequately, resident biodiversity may be reduced or lost. Protected areas also often introduce geographic and ecological isolation, in many ways inherent in a model where such localities are the only places containing natural habitat. Even when reserves function to maintain habitat and resident biodiversity, the latter may well be compromised by separation from other populations and other potential areas to inhabit. Researchers increasingly recognize that despite a growing number of protected areas, isolated reserves usually are incapable of conserving many forms of biological diversity as well as ecological processes (Chape et al. 2003). In regions with heavy loss of natural habitat, species lying outside of protected areas are vulnerable to a variety of adverse impacts as biodiversity becomes increasingly limited to prescribed localities. One possible solution to such shortcomings is to create corridors between reserves, reestablishing connections between protected areas while expanding conservation beyond reserve boundaries through a landscape approach to maintaining habitat and species.

CORRIDORS AND CONNECTIVITY: EXPANDING THE FOOTPRINT OF BIODIVERSITY CONSERVATION

Conservation corridors are landscape features that connect two or more patches of natural habitat in a fragmented environment to restore selected key ecological processes (Soulé and Gilpin 1991; Bennett 1999; Anderson and Jenkins 2006; Hilty et al. 2006). The most familiar form of corridor is a linear corridor, providing approximately straight-line links between blocks of natural habitat over both short and relatively long (tens of kilometers) distances (Anderson and Jenkins 2006). Less familiar is a landscape corridor, a feature involving multiple ecosystems and multidirectional connections among several blocks of natural habitat, often occurring at a regional scale and possibly involving many linear corridors (Alger et al. 2000). Corridors aim to conserve biodiversity through maintaining functioning ecosystems, though due to their frequent incorporation of multiple land uses they also often promote sustainable use of natural resources to minimize human impacts (Bennett and Wit 2001). Corridors have attracted considerable attention in recent years, prompting a series of reviews of the concept and its application to biodiversity conservation (e.g., Bennett 1999; Bennett and Wit 2001; Anderson and Jenkins 2006; Bennett and Mulongoy

2006; Chetkiewicz et al. 2006; Hilty et al. 2006). This growing interest reflects a belief in the potential for corridors to complement protected areas, the former serving to link disconnected reserves which, in many cases, represent the only remaining patches of natural habitat in a particular area.

Ecologically, the concept of corridors has a foundation in island biogeography (MacArthur and Wilson 1967), with isolation and size of habitat block relating to species richness (Diamond 1976); and in macropopulation theory (Hanski 1999), when a species lives in separate patches but moves among these patches to increase local population viability. The ecological processes supported by corridors include the movement of individual animals which provides access to larger amounts of habitat and essential resources and facilitates seasonal and periodic migration (Dobson et al. 1999; Bennett and Mulongoy 2006); maintaining genetic diversity through interaction among multiple populations (Hale et al. 2001); replenishing isolated populations possibly at risk of local extinction (Gilbert et al. 1998; Gonzalez et al. 1998); and providing routes for geographic adaptation in the wake of climate change or other impacts (Channell and Lomolino 2000; Thomas et al. 2004; Hannah et al. 2007; Heller and Zavaleta 2009). Corridors appear in several guises, including wildlife corridors, habitat corridors, greenways, and greenbelts, the final two types often integrating human use into natural habitat (Ahern 1995; Hellmund and Smith 2006). Despite the variety of intentions and names associated with corridors, establishing connectivity in fragmented habitat is inherent in the corridor concept.

Fragmentation generally refers to a condition in which a large area of habitat is broken into smaller pieces (Forman 1995), the resulting mosaic habitat frequently a consequence of human activity (Hilty et al. 2006). Fragmentation is a major cause of biodiversity decline (Anderson and Jenkins 2006). It produces isolation or separation among pieces of natural habitat, with the distance between habitat fragments and the size and shape of those fragments (and, consequently, the amount of edge versus interior, the volume and shape of the core area) all affecting the ecology of a particular landscape or region (Forman 1995). Several important changes can occur as a result of habitat fragmentation and ecological changes that accompany it, including the disappearance of some resident species in a particular isolated area and the introduction of others, as well as ancillary impacts, such as increases in disease (Suzán et al. 2012), that fundamentally alter resident biodiversity.

Corridors can help to counter the detrimental effects of fragmentation through reestablishing connectivity among separate pieces of habitat. Connectivity refers to the extent that plants and animals can move between separate habitat patches (Hansson 1995). Such movement can occur via continuous corridors between patches, composed of uninterrupted altered or natural habitat that supports relocation of species, or via *stepping stone* corridors consisting of separate pieces of habitat arranged in a pattern that serves to link one patch to another (fig. 2.4) (Bennett 1999; Bennett and Mulongoy 2006; Hilty et al. 2006; Saunders 2007). Although corridor habitat might ideally be native to a particular landscape, the critical requirement is that it serves to restore connections between patches; alternative vegetation composition can be acceptable, as long as it enables movement among localities separated by habitat that would not support such relocation of plants and animals (Perrault and Lomolino 2000). Movement can occur over widely varying time scales, ranging from immediate to generational (Hilty et al. 2006). In some settings, connectivity is unplanned, occurring along roads, hedgerows, streams, and similar features where vegetation associated with these features serves to connect one patch to another (Forman 1995). In other settings, connectivity occurs via corridors created

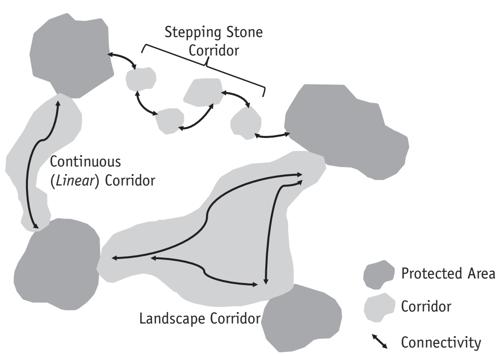

Figure 2.4 Schematic representation of different types of corridor connections linking protected areas.

purposefully to support it, including areas of habitat restored specifically to connect separate localities, riparian buffers along streams, and greenways that serve the needs of ecological connectivity as well as human use (Ahern 1995; Anderson and Jenkins 2006; Hellmund and Smith 2006; Hilty et al. 2006).

Fragmentation frequently occurs due to agricultural activity and its enormous footprint (Laurence 2010). It also results from a variety of resource extraction activities, human habitation and the introduction of associated infrastructure, and modification of habitat by a variety of other land uses (Forman 1995). In the present context, interest particularly focuses on protected areas as remaining fragments of natural habitat and surrounding matrices of mixed land cover types as the consequence of human disruption. The challenges to establishing and maintaining corridors depend on a number of factors, including land tenure and the value of the land and the resources it contains. In a situation where land of considerable value to humans is marked for a corridor, the *opportunity costs* of maintaining or reintroducing species-preferred habitat with restricted human use instead of developing that land become great. Such considerations help to explain the locations of many protected areas, created in localities not particularly valuable for human use, such as agriculture (Gorenflo and Brandon 2005), likely explaining their availability for protection in the first place as well as their persistence. It is tempting to place the greatest challenges to corridor establishment in less-developed countries, where poverty generates greater need to extract resources from the land both for local use and for export (Sanderson 2004; Turner and Fisher 2008). However, resource demand continues to grow in developed countries as well, current activities associated with energy development providing a powerful reminder of the burden that land must bear in many places (Smil 2003; Naugle 2011; Leggett 2014). The need for corridors, and the form that they take, ultimately rests on local conditions—resident cultures and economies both helping to drive fragmentation and, as such, increasing challenges of creating and maintaining functioning corridors.

Despite the focus of corridors on reconnecting fragmented habitats, many remain skeptical of their contribution to conservation (Hobbs 1992; Simberloff et al. 1992; Mann and Plummer 1995; Dobson et al. 1999; Anderson and Jenkins 2006; Margules and Sarkar 2007; Schmiegelow 2007). Nearly two decades ago, Beier and Noss (1998) asked how well corridors perform in restoring ecological connectivity. To date, that question largely remains unanswered, in part because many corridors still are undergoing implementation and performance assessments over multiple years remain largely unavailable. Studies of effectiveness that do exist tend to focus on short, narrow implementations, prompting a recent appeal for examples that are both geographically larger and longer established (Beier and Gregory 2012). Ironically, the large geographic scale often sought can make evaluations of expansive corridors quite challenging. For example, assessments of the Yellowstone to Yukon Corridor extending across 1.3 million square kilometers of northwestern North America often focus on subsections of the entire corridor, or topics such as road impacts and mitigation of related impacts (e.g., Alexander and Gailus 2005; Yellowstone to Yukon Conservation Initiative 2012). Evaluations of the entire Yellowstone to Yukon corridor for certain *umbrella species* that serve as general indicators of effectiveness, such as large carnivores (Merrill 2005), cover its entire extent but show varying success in different parts of the corridor, revealing a major challenge in gauging the effectiveness of such large-scale efforts.

Although the plea by Bennett and Wit (2001) for an online database that provides details on all ongoing corridors remains unfulfilled, examples of such summaries provide a sense of the potential utility of such updates (e.g., Tanzania Wildlife Research Institute and Wildlife Conservation Society 2014; Yellowstone to Yukon Conservation Initiative 2014). Other sources of skepticism include possible negative effects of corridors. Researchers have raised concern about the large amount of edge habitat that corridors introduce, and its impact on resident species (particularly through increased predation), as well as the potential for corridors to help spread pests, disease, and fire (Simberloff and Cox 1987; Bennett 1999; Dobson et al. 1999). Finally, some question the cost-effectiveness of corridors, asking if funds might be better invested in managing existing protected areas rather than expanding conservation, and raising the issue of economic and political cost of committing more land to biodiversity conservation (Simberloff et al. 1992; Dobson et al. 1999).

Despite potential weaknesses and uncertainty about their performance, corridors have been employed in a variety of settings around the world over the past two decades (Anderson and Jenkins 2006; Bennett and Mulongoy 2006). Although it is risky to rely so heavily on an approach whose success remains undemonstrated, the complementary effects of reducing fragmentation and increasing connectivity have a sound basis in ecology, causing many to invest in an unproven approach that *should* work (Bennett 1999). Moreover, given the current rate of biodiversity loss, the greater risk may be to wait until research demonstrates the effectiveness of corridors. A major potential shortcoming in employing corridors is in getting them to function in unprotected settings amid, in the worst case, a combination of human demand and poverty—characteristics of many places on our planet where the greatest biological diversity occurs, including much of the tropics. Designing corridors that persist in the absence of some sort of formal management will be essential to expand the number of potential locations, and to restore key ecological functions.

MODELS FOR CONSERVATION BEYOND PROTECTED AREAS

The parallel between fragments and connectivity in ecology, and protected areas and corridors in conservation, is obvious. Increasing focus on landscape-scale conservation is consistent with growing recognition of a need to maintain habitat, ecosystems, and species at a scale beyond the individual site (Terborgh and Soulé 1999; Anderson and Jenkins 2006; Bennett and Mulongoy 2006; Chetkiewicz et al. 2006; Hilty et al. 2006). Expansion beyond protected areas does not imply that reserves are not important to conservation; indeed, they remain essential to maintaining biodiversity in a world of human use, and the frequently used metaphor *cornerstone* of conservation seems appropriate (LeSaout et al. 2013). Unfortunately, in many instances, protected areas are quite isolated from other natural habitat; as human population continues to increase, driving even more rapid growth in demand for Earth's resources (Mattar 2012), this isolation inevitably will increase. Landscape-scale conservation, with its focus on maintaining additional ecosystem function through connectivity, explicitly addresses the isolation issue and detriments to conservation that accompany it (Bennett and Wit 2001). But two uncertainties emerge. One involves the ability of either protected areas or corridors to conserve biological diversity—the first having been found inadequate in many instances, the latter remaining unproven. A second uncertainty involves potential to establish functioning corridors in the absence of active protection, particularly in developing countries in the tropics where much biodiversity occurs.

Assessments of protected area effectiveness point to management as a persistent source of weakness. Poorly performing parks often have shortcomings involving relationships with local people, planning, monitoring and evaluation, budget, and law enforcement (Dudley et al. 2004). Many of these shortcomings can be addressed through shifts in management, ideally producing well-staffed protected areas with strong environmental education and outreach programs to engage local people, and adequate enforcement capacity. Funding often emerges as a key to solutions, providing the means to obtain necessary equipment, staff, and training (Leverington et al. 2010). But in many places where much of Earth's biodiversity occurs, funding is scarce (Bruner et al. 2004). In lieu of significant increases in financial resources for protected area management, many have looked toward increased integration of local communities—those who lose access to resources when protected areas are created, and who often are responsible for impacts on resulting reserves.

Prior to the past two decades, protected areas have largely been managed by government agencies in a top-down approach that often excluded access by local people. In such management schemes, the government agency holds all authority and responsibility. When management plans and their implementation are effective, this approach succeeds in meeting conservation and other goals (Dudley et al. 2004; Leverington et al. 2010). However, such a strategy relies on management that involves imposing restrictions on activities and limits on access, and field staff to enforce such constraints—an expensive conservation solution that isolates local residents (James et al. 2001; Bruner et al. 2004;

McCarthy et al. 2012). In recent years, management by government agencies has given way to alternative approaches that introduce increasing leadership by local people. Co-managed protected areas share the responsibility of protected area management between government entities and concerned communities. Community-conserved areas, in turn, place full authority and responsibility on concerned communities. These management schemes lie along a continuum, from complete government responsibility at one end to no government involvement at the other (Borrini-Feyerabend et al. 2004).

Given the costs of conservation management, and the large number of protected areas that currently do not function effectively in part due to management shortcomings, expanding government responsibility from reserves to corridors is not an option. Partial or complete integration of community management appears to be more feasible, in large part because such strategies integrate the interests of the very people who would be responsible for managing a particular tract of land (Douglass 1992; Robinson 1995; Argawal and Gibson 1999; Borrini-Feyerabend et al. 2004; Berkes 2004, 2007). Indeed, any government role in corridors presumably would be much more limited than in protected area management, the latter including frequent engagement and negotiation to reach consensus on management actions. Beyond the establishment of corridors, which may require scientific analysis to identify effective locations and conservation goals, and to help arrange any adjustments in land tenure that government might facilitate, corridor management might best be left to concerned communities, or possibly key institutions within those communities (Argawal and Gibson 1999).

Increasing interest in community-based conservation is in part a response to lack of universal success in top-down government management of protected areas, in part a response to an increase in demand by local people to participate in decisions that have an important impact on their lives, and in part recognition that the success of protected areas in the long term requires support of the people living in and near them (Argawal and Gibson 1999; Carey et al. 2000). A variety of specific approaches to community-based conservation exists, depending on the particular protected area, resources, and communities involved. However, community-based approaches have three essential characteristics: (1) communities are concerned about the relevant areas and ecosystems; (2) communities are the major entities making and implementing decisions, and hold the authority to do so; and (3) community actions lead to the conservation of habitats, ecosystems, ecosystem services, and associated elements (Borrini-Feyerabend et al. 2004). Such features reflect a call for local leadership in protected area management and biodiversity conservation made more than a decade ago (Stolton and Dudley 1999). To improve success, these schemes need to balance rights and responsibilities: communities can guide conservation management, but they need to deliver results.

Indigenous reserves are a special case of community-conserved areas, in particular involving peoples with a cultural connection to a particular area often having developed over a long period of time (Oviedo and Brown 1999). Their management involves traditional institutions and guidelines already in existence as part of the fabric of a particular indigenous cultural system (Davies et al. 2013). There is a moral basis for such approaches, providing an opportunity for people culturally associated with an area to guide management of its resources. But there is a functional basis as well. Although conservationists have long recognized that the presence of indigenous people does not guarantee biodiversity conservation (Redford 1991), research has shown that indigenous protected areas often successfully conserve habitat within their bounds (Bruner et al. 2001; Nepstad et al. 2006; Soares-Filho et al. 2006; Ricketts et al. 2010). Indigenous people also frequently possess detailed knowledge of their natural surroundings that can greatly increase understanding of those settings. The combination of conservation success and additional information about local ecology, habitat, and species certainly provides considerable impetus for indigenous stewardship. Recent research has demonstrated that regions with high biological diversity also tend to have high indigenous linguistic diversity (Gorenflo et al. 2012), suggesting some sort of connection between human and natural diversity (Maffi 2005; Maffi and Woodley 2010). Although the functional relationship between these two forms of diversity remains to be identified, the presence of indigenous people within existing ecosystems may help to conserve those ecosystems.

As conservationists look beyond protected areas for a strategy that will effectively maintain biodiversity and some of the ecosystem functions necessary for its survival, they clearly encounter a major challenge. Corridors may address the isolation and fragmentation inherent in protected areas, but guaranteeing success of corridors will likely be difficult without careful management. Although community-based oversight of corridors may be the best approach to ensuring corridor functionality, these large landscape features will almost certainly fall in areas with some human presence or use. Regardless of any commitment by local people to conserve natural resources in a nearby corridor, they too have needs. Because much expansion of conservation should occur where the greatest biological diversity occurs, it likely will involve developing countries in the tropics—areas where reliance on locally available natural resources is particularly high (Carey et al. 2000; World Resources Institute et al. 2005). How, then, can one design corridors that enhance biodiversity conservation amid the demands of local people and in the absence of management and enforcement by government agencies?

Systematic conservation planning often yields enormous benefits to conservation, helping to meet conservation goals with limited funds (Margules and Pressey 2000; Groves 2003; Margules and Sarkar 2007). In response to the question of corridor performance, increased planning input has been proposed to ensure that conservation targets—e.g., species, communities, or ecosystems—are explicitly considered (Chetkiewicz et al. 2006; Cushman et al. 2013). Corridor design and implementation understandably focus on biological goals, where condition, size, and location help to determine the steps necessary to establish specific connection (Simberloff et al. 1999; Noss et al. 2005; Anderson and Jenkins 2006; Lindenmayer and Fischer 2006; Noss 2007). However, as human presence expands across much of our planet, planning will need to incorporate the value of any potential corridor to people as well. An analysis of priority locations for expanding biodiversity conservation, defined in a global gap analysis (Rodrigues et al. 2004), demonstrated that many had relatively sparse human presence, low agricultural suitability, and intact natural habitat (Gorenflo and Brandon 2006)—localities that could accommodate biodiversity protection with little cost to current or future human habitation and agricultural expansion. Employing a similar perspective will help to identify potential corridors that meet conservation aims while providing minimal basis for disruption by local residents. Ideally, corridors can be located in a way that requires little constraint on the actions of local people, placing ecological connections where habitat would be easier to maintain than localities containing valuable resources and human habitation. It would not necessarily protect corridors from the harvesting of biodiversity whose movement they support, notably animals traveling from one protected area to another. In cases where local people do not actively seek these animals, protection would be unnecessary. In cases where these animals are potential resources, community management would need to take steps to provide necessary protection (Zimmerer 2006; Goldman 2009).

Of course, efforts to identify potential corridors between protected areas will not always succeed in discovering areas that meet conservation goals while avoiding locations of potential value to humans. In some instances other considerations of human use will need to be incorporated in conjunction with conservation targets. Here, one might seek localities where potential, or likely, land uses are not incompatible with conservation. One possible solution might be ecoagriculture, the development of landscapes that support sustainable crop production as well as conservation of biodiversity and ecosystems (Zimmerer 1999; McNeely and Scherr 2003; Scherr and McNeely 2007; Ranganathan et al. 2008). In ecoagriculture, movement of plants and animals could occur through a corridor designed to produce crops as well, thereby helping to improve the human condition while contributing to the maintenance of biodiversity. Another possible solution might involve areas associated with reducing emissions from habitat conversion, such as the UN collaborative initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries (UNREDD 2011). Here forest habitat could serve as a means of linking localities, the scale of landscape corridors presumably of greater interest for REDD purposes, but resulting payments potentially available to help offset lost opportunities of harvesting trees and other biodiversity. Finally, there exists the option of conservation concessions, basically paying people to support certain conservation measures in certain localities, often requiring a restriction on harvesting and active protection by community residents (MacKinnon et al. 2008). All three of these strategies have their drawbacks, the first two still susceptible to some sort of resource harvesting despite careful design, the third likely affecting the cultural systems involved due to the infusion of funds and requiring a steady stream of money to support it. Nonetheless, such approaches enable corridor development when it is impossible to identify land of limited value to people.

Designing corridors that consider biodiversity conservation and human ecology may help provide the conditions where localities beyond the bounds of formal protected areas can function to expand effective maintenance of biological diversity (Machlis et al. 1997; Field et al. 2003). Ultimately, employing a strategy to conserve biodiversity that looks outside of protected areas will be extremely challenging. Although their functionality remains to be determined, corridors theoretically provide the means of expanding beyond reserves that enables restoration of key ecosystem characteristics, primarily connectivity. In the absence of purposeful restriction of human use, placement of such corridors is of paramount importance—requiring locations unattractive to people for resource production or extraction. Of course, a corridor so-placed today may be unsuccessful in the future. Soaring demand in coming years may drive people to consider resources or thresholds of potential use presently unacceptable; evolving technology may make an area currently of limited utility much more important to future residents. Nevertheless, through careful analysis and implementation, corridors between protected areas can yield a network of broader ecological and species conservation in the absence of human pressure, where people live and work amid a web of functioning nature that maintains species as well as other characteristics, such as functioning ecosystems and the services they yield that are quite important to poor people in developing nations (World Resources Institute et al. 2005).

CONSERVING BIODIVERSITY IN THE TWENTY-FIRST CENTURY

Some of my earliest memories are of attending films in the 1960s showing East African wildlife. Decades before the term "biodiversity" was first uttered, the number of humans on Earth was less than half the current total, protected areas in most countries were in their infancy, and extinctions usually referred to dinosaurs rather than modern species. Recently having emerged from colonial control, the savannas and woodlands of East Africa seemed to stretch forever, as did the vast herds of herbivores that they supported. Human impact was limited to a handful of hunters who harvested a few individual animals from populations that in many cases numbered in the tens of thousands. A half-century later, we live on a different planet. Human population has reached numbers almost unimaginable. Human demand has increased even faster, with a nation achieving *developed status* marked in part by per capita consumption at levels far beyond sustainability (Assadourian and Renner 2012). The result is the first human-induced mass extinction. The only hope for much of our planet's biodiversity is well-designed and well-managed protection. Achieving such protection increasingly calls for expansion beyond the protected areas currently employed.

The strength of a protected area model is that when protection is intact, it works as a means of conserving biodiversity and associated ecosystems. The weakness of this model is that its impact usually is limited to the bounds of the reserve, introducing fragmentation and other undesirable consequences that likely will compromise long-term conservation success. To complicate matters, many protected areas simply do not effectively conserve resident biodiversity. The preceding pages describe a more broadly focused, multifaceted approach to biodiversity conservation. This approach begins with existing protected areas. But it recommends expansion of conservation to selected localities beyond the official protected area network, through introducing various types of corridors that link protected areas to help reduce the isolation of reserves through softening the edge of conservation. Desirable localities for corridors are those meeting targets for biodiversity conservation that are not particularly valuable for human use, recognizing that compromising on either or both of these criteria may be necessary depending on particular situations. Any land use in localities beyond the bounds of existing protected areas that seeks to maintain biodiversity requires careful, purposeful planning, providing a functional level of protection to target species in habitat that comprises a mosaic of natural and human components.

In many ways, the technical solutions for expanding beyond protected areas either exist or are within our reach. Admittedly, this chapter places faith in corridors—promising but unproven—as a means of reducing fragmentation and increasing connectivity, appealing to the concept's grounding in current ecological theory and a recognition that amid mass extinction solutions must be designed and implemented quickly (Bennett 1999). Increasingly improved datasets of species and habitat, many of them geographic information system data with the ability to support spatial analyses and creation of precise maps, provide an opportunity to define priorities for conservation based on particular biological characteristics—for instance, range of occurrence, conservation status, and level of threat. Other data, again often in geographic information system format, enable identification of localities with dense human occupation and land use that is incompatible with biodiversity conservation, as well as identification of areas likely to experience human pressure due to the presence of certain resources. Systematic methods for conservation planning enable consideration of key data describing the physical and human geography of particular localities, helping to identify places that meet biological criteria while avoiding human impacts. In the absence of government-defined protection, with its associated constraints on human use, it will be essential to place corridors in localities that meet conservation goals but hold little attraction for people.

The focus of this volume recalls what may be the greatest challenge of conserving global biodiversity in the twenty-first century: maintaining species, along with the habitat essential for their survival, in less-developed countries where poverty dominates the human condition. Solutions must be dual-focused, working for nature and people. This proclamation appeals to the reality of a world rushing towards 9.6 billion human residents in a few decades. The challenge of expanding conservation beyond protected areas is to restore ecological connectivity that minimizes human costs and management requirements. The reliance of the poor on locally available resources will continue to make conservation beyond protected areas a challenge. Careful, strategic design of conservation elements beyond protected areas can help to address this challenge, expanding the footprint of conservation with minimal cost to people who possess the mixed blessing of living in areas important to maintaining Earth's biological heritage.

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