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ABSTRACT

Protected areas (PAs) are an important component of the global conservation strategy and understanding the past drivers of land protection can inform future conservation planning. Socioeconomic and policy drivers of protection vary through time and space, but a lack of spatio-temporal data limit the ability to conduct retrospective analyses of PAs. We developed a spatio-temporal database covering 90% of area in PAs in northern New England in the U.S. to quantify trends in the extent, rate of increase, ownership characteristics, and level of protection from 1800 to 2010. We found an accelerating rate of protection and an increase in the proportion of privately owned PAs. There was an increase in reliance on conservation easements for protection, and an increase in the proportion of PAs that allow resource extraction. We found three distinct time periods of PA growth, each characterized by new policies and a broadening set of conservation tools. The era 1999-2010 had the most rapid rate of land protection, representing more than four-fold and 20-fold increases over the eras 1980-1999 and 1800-1979, respectively. We projected future PA growth based on past trajectories and found that current goals to protect 70% of New England's forests from development would require a 42% increase in the rate of protection over the 1999-2010 era. Our analysis of the historic and current trends in protection in northern New England underscores: (1) the significant influence of expanded policy and economic drivers guiding protection; and (2) the importance of developing new conservation innovations for achieving future gains in protection.

Keywords: Protected areas; Conservation planning; Conservation easements; Land-use change; Conservation history; Working landscapes

INTRODUCTION

For over a century, land protection has been a key global conservation strategy pursued by diverse public and private organizations. Conservation actors employed a wide array of conservation tools to protect a broad and dynamic set of ecological, economic, and social values. As a result, the current mosaic of protected areas (PAs)—those areas with legal, jurisdictional, or other mandates that protect them from conversion from natural land cover—reflects the cumulative effects of both strategic and opportunistic transactions driven by evolving conservation, economic, and policy mechanisms. In order to inform future conservation planning, we sought to understand the socioeconomic and policy factors that influenced the rate, type, and distribution of past protection (Tear et al., 2005; Davies et al., 2011; McDonald and Boucher, 2011).

To be successful, strategic plans must not only identify and pursue high-priority objectives based on ecosystem values and services, but must also link these conservation priorities to salient socioeconomic priorities (Cronan et al., 2010; Prendergast et al., 1999). In the U.S., organizations that engage in strategic planning are more effective at protecting land (Chang and Aldrich, 2010). Though conservation *planning* is an inherently long-range endeavor, conservation *action* is influenced by short-term constraints, such as immediate conservation priorities, internal and external socioeconomic pressures, and real estate market conditions, all of which vary through time and space (Halpern et al., 2013). Despite significant gains in assembling PA information at different scales, it is still difficult to conduct retrospective analyses of land protection – thereby limiting the ability to use past trends to inform future conservation goals and strategies.

There has been a lot of work done to understand the spatial patterns of PAs, but due to a lack of data, studies assessing the temporal trends in PA expansion are limited. The spatio-temporal studies that do exist tend to focus on either small geographic regions where data are readily available (McDonald et al. 2007; Cronan et al. 2010) or the global scale where data are coarse and incomplete (Chape et al., 2005; Jenkins and Joppa, 2009; McDonald and Boucher, 2011). Global analyses tend to smooth regional trends and may not detect socioeconomic drivers of PA growth at the sub-country scale (Zimmerer et al., 2004) or trends specific to biomes and ecoregions (Jenkins and Joppa, 2009). Zimmerer et al. (2004) found a 153% increase in the global coverage of PAs from 3.48% in 1985 to 8.82% in 1997, but found that the rates of expansion, level of protection, and drivers of protection were geographically heterogeneous, indicating that global trends encapsulate diverse patterns and may not reflect specific regional drivers and trends.

Another limiting factor of some global analyses of PAs is the exclusion of some forms of protection that may be common in some regions but not others. Conservation easements, which are voluntary agreements between a landowner and a conservation organization to extinguish some management rights for the purpose of protecting conservation value, have emerged as the leading tool for protecting private land in the U.S. (Kiesecker et al., 2005; Lewis et al., 2002; Merenlender et al., 2004; Rissman et al., 2007; Wallace et al., 2008). They are appealing alternatives to fee simple acquisitions, in which a landowner purchases the property and all its implied management rights, in part because of their cost effectiveness and social acceptance as a market-based, voluntary conservation tool (Plantinga and Miller 2001). Unfortunately, conservation easements and other forms of private PAs may be overlooked by global databases such as the World Database on Protected Areas (WDPA; e.g., Crouzeilles et al., 2013). Moreover, PA databases focus on active land protection and ignore lands protected through passive means, which are spatially heterogeneous and difficult to track, in part because they are typically enacted by local or regional policies. Passive protections, such as regulatory measures that protect specific natural features or restrict management actions, may be significant, especially in the case of wetland protection and buffers around waterbodies, as are common practices in the U.S.

In this paper, we present a spatio-temporal analysis of land protection in the northern New England (NNE) sub-region of the U.S.—including the states of Vermont, New Hampshire, and Maine. Our objectives were to: (1) create a landscape-scale, spatio-temporal dataset of land protection for NNE to document the region's conservation history; (2) quantify temporal and spatial patterns in the rate, ownership type, and level of protection in the region; (3) identify the policy and socioeconomic conditions characterizing different periods of PA growth; and (4) assess future trajectories based on past conservation trends. By examining the sequence of historic conservation patterns in the region, we provide insights about which policies and economic drivers were characteristic of periods with accelerated land protection. We are also able to provide insights about how past conservation innovations may contribute to future PA growth potential.

METHODS

Study Area

The New England region of the U.S. has a long history of significant shifts in land cover (Foster, 2002). Through the 18th and 19th centuries, there was widespread clearing of forests for agriculture, followed by farm abandonment and subsequent forest regrowth. Simultaneously, there was a major expansion in regional population and urbanization. Today, development pressures radiate not only from major population centers such as Boston and New York City, but also from growing regional service centers such as Burlington, Vermont and Portland, Maine. As a result, the NNE sub-region faces a tension between rising demands for human use, and growing recognition of the need for conservation to provide ecosystem services (Stein et al., 2007). Over the last two centuries, New England has pioneered some notable land protection innovations, including the first land trust in the U.S. and the first large-scale working forest conservation easement (Foster, 2002; Levitt, 2005; Meyer et al., 2012).

NNE encompasses 133,054 km^2 or 71% of the New England region, and contains 77% of New England's 3.6 million-ha portfolio of land protected from development. NNE is predominantly privately owned, with relatively small amounts of land in federal or state ownership – 8% for Vermont, 16% for New Hampshire, and just 5% for Maine (Natural Resources Council of Maine, 2013). Nonetheless, there are several very large blocks of public land within NNE, including the White Mountain National Forest (WMNF), the Green Mountain National Forest (GMNF), and Baxter State Park. The region is heavily forested (Vermont 67%, New Hampshire 67%, and Maine 84% forest cover; Fry et al. 2011), and each state has significant commercial timberland holdings. Since the late 1990s, many large-scale working forest conservation easements have been secured, mostly through partnerships between environmental nongovernmental organizations (ENGOs) and large forest products and land management companies (Ginn, 2005; Fairfax et al., 2005). Beyond these large blocks, there are tens of thousands of smaller dispersed parcels of public and private lands that are protected from development under various mechanisms. The objectives of PAs in the region broadly include conservation of biodiversity, provisioning of ecosystem services, public open space, recreation, and natural resource extraction such as timber harvesting.

Composite Conservation Database

When we began our study, there were no comprehensive datasets of conserved lands in the NNE region that included information regarding PA date of establishment. We used multiple sources and approaches to augment existing geospatial datasets to create a comprehensive database that included parcel-level data for date of protection.

The Nature Conservancy's (TNC) Secured Areas Database (Anderson and Sheldon, 2011) provided our reference dataset. Although temporal information is generally lacking, this dataset represents the most current and spatially complete accounting of PAs in the study area, and includes extensive information about the type of ownership, management, and level of protection of each PA. Anderson and Sheldon (2011) describe the level of PA protection using the GAP rating system (Crist et al., 1998), where all PAs assigned to GAP categories 1-3 are permanently protected from development or conversion from natural land cover. Specifically, GAP 1 PAs have a mandate to maintain a natural state, GAP 2 PAs have a mandate to primarily maintain the natural state but allow some provisions to suppress natural disturbances, and GAP 3 PAs allow extractive uses. (For a crosswalk between GAP statuses and the IUCN categories used globally, see Anderson and Sheldon (2011)). Given that this dataset includes PAs assembled over two centuries, it is important to note that GAP status was, in many cases, assigned to each PA long after it was protected and generally reflects the most recent known level of protection. We recognize that there is a large range of voluntary and legal protections represented across the PAs in this study, including many that do not have sufficient level of protection to warrant an IUCN ranking (e.g., GAP 3 status). PA databases commonly include lands owned by municipal and education entities, even if the land lacks formal protection. We note here that our database excludes passive protections (i.e., those without an interest in full or partial rights to a property) resulting from regulatory actions, such as no-development zones in and around wetlands that are common within the study area.

In order to complement the TNC data, we collected individual datasets from state management agencies, including Maine Department of Conservation Conserved Lands (*ME-DOC 2010*), New Hampshire GRANIT Conservation/Public Lands (*NH-GRANIT 2010*), and Vermont Center for Geographic Information Conservation Lands Database (*VCGI 2010*). Some of these state-derived datasets appear to have provided original information for the TNC dataset. However, these datasets have since been managed in parallel, and inconsistencies between them are common and oftentimes significant. The state databases were invaluable for this project because they included considerably more information regarding the date of establishment for PAs than did any of the national-level datasets.

We also used two federal government datasets: the National Park Service Land Status database for Acadia National Park, and the United States Forest Service Automated Lands Program for the GMNF and WMNF. These sources contained fine-scale comprehensive temporal information for conservation parcels within these federal jurisdictions. Lastly, a dataset from the Forest Society of Maine—a land trust focused on working forest conservation—was used in Maine to augment some information absent in other datasets.

All geographic analyses were done with ArcGIS 10.1 (ESRI, 2012) and ArcPy within Python (Python, 2012). We used TNC 2010 as a reference map and combined all other datasets using a common datum. Because of the idiosyncrasies of the multiple input datasets, we used the intersect, union, and update tools to combine spatial and attribute data from disparate datasets. We then used internet resources—including websites that listed park histories, state and local reports, and other land conservation histories—and initiated dozens of personal communications via telephone and email to state and local agencies, ENGOs, and other land managers to document the year specific parcels were protected. We first obtained temporal information for the largest and most well-known parcels throughout the study area. The implications of this for potential bias are explored below. We added the year of protection for each PA to the spatial dataset, maintaining the greatest spatial and temporal resolution simultaneously. Specifically, when combining datasets that represented the same protected area with different numbers of polygons (i.e., the spatial resolution was inconsistent), we retained the finest-resolution polygons available as long as temporal information was available at that scale. For instance, Acadia National Park is represented in the TNC dataset by 58 polygons, but we were able to use the National Park Service Land Status database to obtain years of protection for 341 unique parcels that were protected over a 92-year period, thus significantly increasing the spatial and temporal resolution of the dataset. We used the identity tool to assign the year of protection to the smallest polygon possible, using a 100 m edge tolerance to account for border inconsistencies. To ensure our temporal sample was not biased against small parcels, we compared the probability distributions of parcel size in the spatio-temporal dataset with that of the spatial-only dataset and found similar, non-biased log-normal distributions.

A major challenge of compiling this dataset was determining the most appropriate unit of conservation transaction, or project. Some individual conservation transactions are comprised of hundreds of individual mapped polygons. For example, some very large easements span many townships, some of which are not contiguous. In other examples, multiple polygons are necessary because of islands in water bodies, inholdings, and other spatial ownership anomalies. While TNC 2010 generally contained the cleanest spatial information, it often had less spatial resolution for specific PAs than did state or federal datasets. Therefore, when we identified a year of protection for an area smaller than the whole of a TNC polygon, we used these other datasets to separate the TNC polygon into smaller constituent polygons, thereby increasing our spatial and temporal resolution for that PA. In general, the composite temporal dataset included substantially greater spatial resolution than the TNC 2010 dataset, particularly for large blocks of PAs such as national forests, national and state parks, and large private ownerships.

Our composite conservation dataset contained 16,128 unique polygons, and included temporal data for 11,407, or 71% of the polygons. Given our concerns that the aforementioned geoprocessing may have introduced errors into the compiled dataset, an accuracy assessment was performed using TNC 2010 as a baseline. Results indicated that the TNC 2010 dataset accounts for 2,646,863 ha, while ours includes 2,757,525 ha. This difference of 4% is largely explained by our inclusion of two major PAs that are not included in TNC 2010: the 36,000-ha Elliotsville Plantation property which lacks formal protection but is owned by an ENGO; and the 146,000-ha Moosehead Region Conservation Easement which has only recently been enacted. Adjusting for these parcels, our dataset has 2.7% fewer hectares than TNC 2010, which is explained mostly by the inclusion of some large water bodies in TNC 2010 and, to some degree, by edge smoothing in our dataset that occurred during geoprocessing.

Past Eras and Future Trajectories of Conservation

We sought to identify distinct land protection eras in the region that reflected the dominant policy and socioeconomic conditions underlying conservation efforts at the time. In order to identify these distinct eras, we combined knowledge from prior work that evaluated policy and incentive-based conservation trends in the U.S. (see, for example, Fairfax et al., 2005; Foster, 2002; Ginn, 2005; Lilieholm et al., 2013) with observed changes in the rate and type of protection uncovered in the data as indicated by inflection points in the rate of accretion of cumulative area of PAs.

Once these eras were identified, we used ordinary least-squares regressions based on the number of hectares protected during each of three historical time periods to extrapolate linear trajectories of land protection. First, the trajectories were used to compute the expected number of hectares that could have been attained in 2010 if each period continued its linear trend from the last year of that era. Second, we projected forward from 2010 to extrapolate the linear trajectory from each era into the future. Third, we compared our three trajectories to what would be required to achieve the Wildlands and Woodlands vision (W&W) of a sustainable landscape in the 21st century. In the W&W report, leading conservation scientists from the region proposed protecting from development 70% of New England's forests, or 12 million ha, by 2060 (Foster et al., 2010). Our NNE study area covers 78% of the total 12 million ha of terrestrial area considered in the W&W vision, and includes approximately 82% of the forests and wetlands. Therefore, we used a study area-adjusted target of 10 million ha of protection to meet the W&W goal.

RESULTS

Composite Conservation Database

The PA portfolio includes 2,757,525 ha, or 21.7% of the entire study area, including 19.4% of Maine, 29.0% of New Hampshire, and 22.5% of Vermont (Table 1). About 1.44 million ha or 52.3% of the portfolio are in fee simple ownership, whereas the remaining 1.31 million ha or 47.5% of the portfolio include conservation easements or other restrictive covenants. The less than 10% of the study area that is publicly owned provides 46% of the PA portfolio (including 3% that is also encumbered by easements). Another 45% is private land conserved through easements, and the remaining 9% is privately owned land that is presumed to be protected but which lacks documented or formal legal protection. The highest percentage of area in PAs protected through easement is in Maine (59%), while Vermont has 38%, and New Hampshire, with the very large WMNF in public ownership, has only 29% of PAs under easements. ENGOs own 236,985 ha in fee without easements and an additional 61,113 ha in fee that are encumbered by easements held by third parties, such as state agencies or other ENGOs.

Temporal Patterns

The portion of the composite database with linked temporal data represents 2.51 million ha of 2.76 million known protected hectares, or 90% on an area basis (Table 1). This represents 88% of the PA portfolio in each of Vermont and New Hampshire, and 92% of Maine. In addition to these PAs, our data include spatial information for an additional 243,291 ha (9% of the total PA portfolio) for which we lack data on the year of protection. Our temporal results presented hereafter exclude PAs with unknown establishment dates.

Overall, there has been an increasing rate of land protection in the study area (Figure 1 and Figure 2). For example, it took 190 years (1800-1990) to protect the first million hectares, but only another 13 years (2003) to protect the second million. More than 40% of the total area protected has been added since 1999, while it took roughly 170 years to reach the first one-third of the current area protected. This accelerating rate of protection is most pronounced in Maine, where 71% of the state's total PA portfolio was protected in the last two decades (Table 2). With its early protection of the WMNF under the Weeks Act of 1911, New Hampshire exhibits a bimodal temporal distribution, with sharp increases in PAs in the 1910s and again in the 1980s (Fig. 1 and Table 2). While there are variations in the rate of change in each state, there are regional trends showing sharp increases in the growth of PAs in the 1920s – 1940s, and again in the late 1990s (Fig. 1, insets).

Three Conservation Eras

Era 1: Rise of Public Land Acquisition - 1800-1979

The period of protection in NNE from 1800 to 1979 is characterized by an evolving suite of broad public conservation objectives including: (1) watershed protection, as exemplified by the 1911 Weeks Act which led to the creation of the WMNF and GMNF; (2) open space and recreation, which were evident in the protection of Acadia National Park, the Appalachian Trail, and countless small-scale community PAs; and (3) wilderness protection, typified by Baxter State Park, which while funded by a private individual, was primarily driven by and for public values. Generally, this 190-year era consisted of a slow, incremental expansion of PAs, largely driven by public acquisition of both parks and multiple-use forests. Federal and state funding mechanisms, including the 1964 Land and

Water Conservation Fund, made possible both large blocks of protection, as well as incremental expansions of existing core areas (Meyer et al., 2012).

Of the 11,452 ha included in our dataset for the years prior to 1900 (Table 2), nearly 11,000 ha are contained in one parcel: the Second College Grant in northern New Hampshire, which was acquired by Dartmouth College in 1807. Incidentally, this parcel is rated as GAP 3 and is an example of a PA that is presumed to be protected from development by virtue of being owned by a non-profit educational institution despite the parcel's lack of formal legal protection from development. Based on the history of community forest protection efforts that took place in this early era (e.g., town forests and open spaces), it is likely that some of the approximately 243,000 ha for which we lack the year of protection were actually protected prior to 1900.

Figure 3 reveals that in this early era, protection was spread across the three GAP statuses, with a core of GAP 1 (e.g., wilderness areas) noticeable in the WMNF, surrounded by buffers of GAP 2 and 3, where some forms of management are allowed. In this period of 180 years, 820,000 ha or 30% of today's total, were protected at an average rate of about 4,500 ha/yr, or 0.04% of the total study area per year (Table 3).

Era 2: Growth of the Land Trust Movement - 1980-1998

The middle era, beginning about 1980, is characterized by a boom in the creation of land trusts in the region and across the U.S. that protected private land from development while incremental public acquisitions continued approximately linearly (Figure 1). Again, federal policy—this time in the form of the Uniform Conservation Easement Act of 1981 and subsequent tax legislation that made charitable donations of land for conservation easements tax deductible—allowed private landowners and ENGOs to work together to protect private property. Advances in land use planning, including Smart Growth principles and community design (Daniels and Lapping, 2005), spurred an interest in open space protection. This era marked the beginning of land trusts working in concert with state and federal agencies as well as private landowners. As of 2010, the region had 157 land trusts, including 88 in Maine alone (Land Trust Alliance, 2011). Some of these land trusts work at the community scale, while others protect lands at regional or state levels.

Acting with new policies and tools, land trusts built on past innovations to drive the protection of an additional 459,228 ha in this 19-yr period – an average of 24,170 ha/yr representing a 5.3-fold increase in the rate of protection over the previous era (Table 3). The rate at which the entire study area was being protected rose from 0.04% per year in the previous era, to 0.19% in this second era. The use of conservation easements accelerated in all three states, and GAP status 3 became more common (Figure 3).

Era 3: Emergence of Large Landscape Conservation - 1999-2010

Since 1999, there has been an even sharper rise in the rate and extent of overall area protected, driven largely by easements on private ownerships (Figure 1). In particular, Maine's 1999 Pingree Easement of about 300,000 ha became a landmark working forest conservation project and remains the largest easement in the U.S. The rise of working forest easements as a conservation tool used by land trusts and other ENGOs to protect large blocks of forest was evident in all three states in this era. A widespread divestiture of land holdings by vertically integrated forest products companies made many of the large-scale conservation projects of this era possible (Ginn, 2005; Lilieholm et al., 2010), although this was not the case for the Pingree Easement. It is notable that in this era two ENGOs, The Nature Conservancy and The Appalachian Mountain Club, secured landscape-scale PAs that combined ecosystem reserves with working forests. In addition to promoting individual large projects, large landscape conservation projects have also endeavored to expand existing PAs.

The average size of conservation easements increased sharply from 58 ha per easement prior to 1999, to 469 ha per easement in 2010. One effect of these easements was an increase in the relative area in GAP 3 status compared with other GAP statuses (Figure 3). Four of the six large working forest easements are in Maine, which has been the recipient of nearly $54 million of Forest Legacy Program (FLP) funding as of 2012 (U.S. Forest Service Forest Legacy Program, 2012). Based on FLP, Maine received 20% of the total funds allocated to the 20 northeastern states in the program; Maine, New Hampshire, and Vermont combined received 40% of the total, protecting 399,830 ha.

Between 1999 and 2010, 1.2 million ha or 44% of the total portfolio was protected at an average rate of 102,542 ha/yr. This era had 4.2- and 22.5-fold increases in the rate of protection compared with the second and first eras, respectively, thus exhibiting a rapidly rising rate of protection during progressively shorter time intervals.

Evaluating Future Conservation Trajectories

To assess the influence of conservation patterns and innovations on the trajectory of PA growth, we extrapolated the trajectories from the end of Eras 1 and 2 into the future and compared them to what actually occurred. We used this approach to project what could have happened without the influence of new conservation policies and drivers, and to highlight the increased gains made in each era. The top graph in Figure 4 depicts how a simple continuation of trajectories from the first two eras would have resulted in substantially fewer hectares being protected by 2010 than actually occurred. For example, if the conditions that spurred the beginning of the Land Trust Movement era had not occurred, the projected incremental increases witnessed during the Public Land Acquisition Period (Era 1) would have only protected 39% of the hectares that were actually protected by 2010 (Figure 4 and Table 3). Similarly, if the large working forest easements driving the Large Landscape Conservation Period (Era 3) had not occurred, only 59% of hectares actually protected would have been protected based on extrapolation of Era 2. While these results are hypothetical, they illustrate that each successive conservation innovation dramatically altered the future rate of PA growth. Future conservation strategies may be able to induce similar non-linear gains.

We also used the trajectories from each era to project potential PA growth forward from 2010, and compared the projected future gains to the conservation target in the W&W vision (Figure 4). Using results from the linear extrapolation of each era, we estimated that if the trend from the most recent Era 3 continues, the W&W target of 70% area protection could be achieved in 2089 (Table 3). In contrast, based on extrapolated trends from Era 1 and 2, it would take 1,179 and 381 years, respectively, to reach our study area-adjusted target of 10 million ha. Meeting the 50-year goal set in the W&W vision would require the protection of 145,456 ha/yr—42% higher than what was achieved in the most recent era. While this 1.4-fold (Figure 4) increase in the rate of land protection over 50 years seems ambitious, it represents only a fraction of the 5.3- and 4.2-fold increases that occurred in the shorter periods of the two most recent eras. If passive protection measures, which are not represented in our PA database are factored in, the rate of protection required achieve the W&W goal will likely be lower.

DISCUSSION

Our analysis examined temporal patterns of conservation in a large region of New England over two centuries. Due to limited temporal data, past temporal analyses of PA growth have typically relied on comparing the extent of PAs at two or more isolated intervals and have likely reported inflated rates of PA expansion that were the result of improvements in data rather than actual increases in the extent of PAs (Jenkins and Joppa, 2009). Here we were able to use a nearly complete spatio-temporal dataset of PAs to quantify the annual rates of expansion and extents of PAs on continuous basis and identify periods when sharp rises in the rate of protection occurred.

The continually increasing rate of protection in NNE culminated in the last decade when there was intense growth in land protection driven by significant public and private investments in large landscape conservation projects. These most recent gains were made possible in large part by the intersection of four conditions: (1) a commitment by the conservation community to protect working landscapes from development as a way to ensure large blocks of forests and the ecosystem services they provide—such as water purification and flood control—remain intact; (2) the maturation of conservation easements as a financially efficient tool that appeals to both landowners and conservation partners; (3) the ability to leverage public sources of conservation funding and attract substantial private investments; and (4) an economic climate that spawned numerous, large landownership transfers from vertically integrated forest products companies to timber investment management organizations and real estate investment trusts. Based on our evaluation of past trends and aggregated impacts over two centuries of conservation effort in NNE, we offer the following lessons to inform future conservation planning.

First, our results highlight the importance of specific events and changing social and economic drivers on the progression of land protection. While our data are not sufficient to say conclusively that increases in the rate of protection in the early 1980s are due solely to the advancement of conservation easement and charitable giving tax policies, it would be hard to argue against their collective influence on the ability of land trusts and other ENGOs to make these significant gains in land protection. Even more apparent in these data is the aforementioned effect of large timberland transactions that allowed for large conservation easements. The lesson here is that unforeseen conditions in financial markets triggered widespread land transactions (Lilieholm et al., 2010), which then made conservation easements an attractive revenue source to new owners, thus providing opportunities for the conservation community. The ability of conservation organizations to capitalize on opportunities during such shocks undoubtedly hinges on their preparedness in prioritizing areas for protection, their ability to partner with landowners and other organizations, their financial agility, and the breadth of available land protection tools.

Second , our data show that the recent high rates of protection occurred mostly in GAP 3 status easements, as opposed to lands with more stringent levels of protection (e.g., GAP 1 and 2). This suggests there has been a broadening of conservation to include the protection of natural resource utilization and related socioeconomic benefits of large, unfragmented ecosystems. Our results for the NNE sub-region of the U.S. contradict the slight shift toward PAs focused on strict protection rather than resource utilization in North America from 1985 to 1997 (Zimmerer et al. (2004), but paradoxically are consistent with the global trend during the same time period. As conservation easements have been shown in some cases not to have the same ecosystem protection level as some forms of fee-owned lands with stricter protection status (i.e., GAP 1 and 2; Rissman et al., 2007), our data could suggest an overall decrease in strict ecosystem protection on a per-hectare basis. Conversely, conservation easements, particularly those with a focus on resource management, have made possible the vast gains in PAs and have incentivized landowners to maintain large blocks of intact forest. Unique opportunities, such as those that arose during the land ownership transition of the 1990s and 2000s provided ideal conditions for securing easements that contributed to the protection of large landscapes.

Third, our hypothetical analysis of what could have occurred if previous trends had continued demonstrate that in isolation trajectories of land protection during narrow periods of time are not necessarily good predictors of future conditions. Though in NNE our study showed accelerating gains in protection in response to specific conditions and conservation innovations, there is risk that other conditions or the absence of new innovations could cause a deceleration in protection. For instance, since commercial timberland ownership in the region has more or less stabilized compared with the large transactions that occurred in the 1990s and 2000s, we would not expect new gains in working forest-related PAs to continue at the rate achieved over the last decade. Furthermore, there are limited opportunities to promote this type of conservation transaction, as many of the large, intact forestland ownerships are already under some form of protection from development.

Fourth and importantly, the effects of past conservation innovations are cumulative, meaning that new policies and conservation tools add to existing practices that persist through time. For instance, the boom in land trusts in the middle era left the region with a strong infrastructure of conservation organizations. Those new organizations went on to lead the next era's huge increase in PAs. In Maine, 81% of the PAs under easement are stewarded and managed by land trusts, as opposed to public agencies. This growth in ENGO conservation leadership in the region is an example of the findings of Zimmerer et al. (2004) suggesting that strong conservation leadership is a key ingredient for growth of PAs worldwide. Furthermore, PAs protected in previous eras often served as cores around which additional tracts were protected. For instance, several PAs from the first era—e.g., Baxter State Park, the Appalachian Trail, and the WMNF—have been expanded through a combination of public and private protection projects, and now function as strictly protected cores within large landscape assemblages of PAs.

Past innovations, such as those that stimulated large landscape conservation, will stay with us into the next era, which will undoubtedly offer its own conservation innovations. For example, across New England and elsewhere, there are growing numbers of regional conservation partnerships in which existing ENGOs, public agencies, and communities collaborate at regional scales to build large landscape PAs (Labich et al., 2013). Prospects of payments for ecosystems services, carbon markets, and other market-driven conservation incentives permeate the conservation movement. It remains to be seen whether the recent gains in PAs from large-scale resource management conservation foretell a future that continues to shift toward more incentivized and market-driven conservation, or whether regulatory and public ownership strategies return to the forefront. Regardless of what the future holds, the 200-year history of conservation innovation in New England offers hope for future efforts to protect ecosystems and their myriad ecological, social, and economic benefits in the face of rising human populations.

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Figures

Table 1. Summary of protected areas by type of protection and ownership for three states in New England as of 2010. Columns show number of hectares protected and percent of total protected area for each state. Rows sum to the total area protected in each state, and the percent of each state that is protected is shown on the bottom line.

	Maine		New Hampshire		Vermont		Total for study area	
Protection type	hectares	%	hectares	%	hectares	%	hectares	%
Fee simple								
Ownership								
Public	470,273	30.4%	418,754	62.1%	308,108	57.2%	1,197,135	43.4%
Private non-profit	164,217	10.6%	50,217	7.4%	22,551	4.2%	236,985	8.6%
Private	1,261	0.1%	6,801	1.0%	509	0.1%	8,571	0.3%
Fee sub-total	635,751	41.2%	475,773	70.6%	331,168	61.5%	1,442,691	52.3%
With conservation easement								
Ownership								
Public	9,423	0.6%	28,698	4.3%	35,630	6.6%	73,751	2.7%
Private non-profit	41,610	2.7%	11,670	1.7%	7,833	1.5%	61,113	2.2%
Private	854,170	55.3%	156,823	23.3%	163,870	30.4%	1,174,862	42.6%
Easement sub-total	905,204	58.6%	197,191	29.2%	207,332	38.5%	1,309,727	47.5%
No data	3,615	0.2%	1,270	0.2%	222	0.0%	5,107	0.2%
Total area protected	1,544,570	100.0%	674,233	100.0%	538,722	100.0%	2,757,525	100.0%
Percent of state protected		19.4%		29.0%		22.5%		21.7%

Figure 1. Conservation timeline by ownership and protection method. The complete dataset includes protected areas as early as 1807, but due to the small increase in protected area growth in the 19th century, this figure shows data only back to 1900. Note that this timeline does not include approximately 243,000 ha for which we have no year of protection. Adapted from Lilieholm et al. (2013).

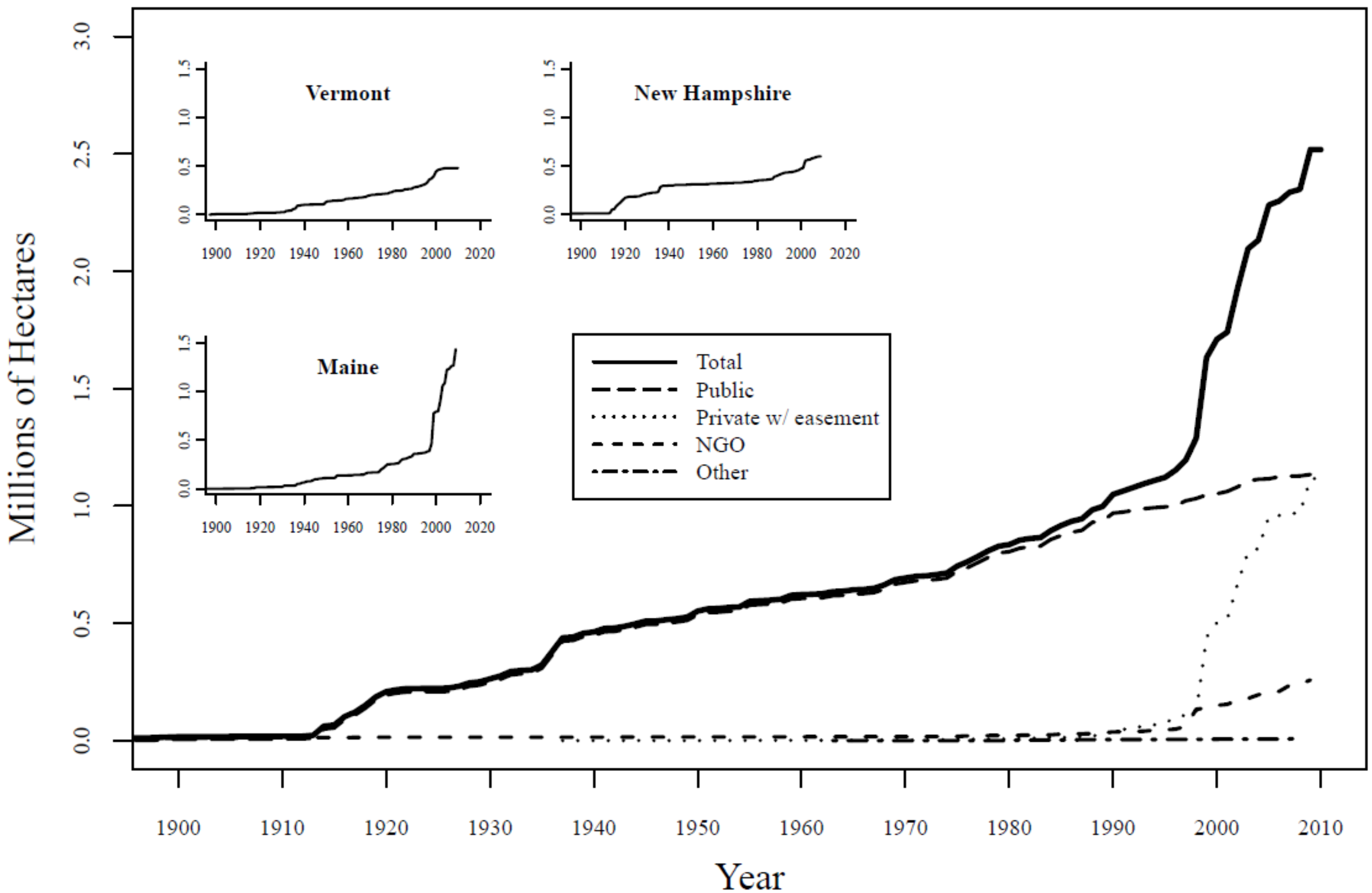


Figure 2. Protected areas by decade in which land was protected and whether it is under easement or is protected by fee simple ownership. Protected areas for which the year of protection is unknown are shown as No Data.

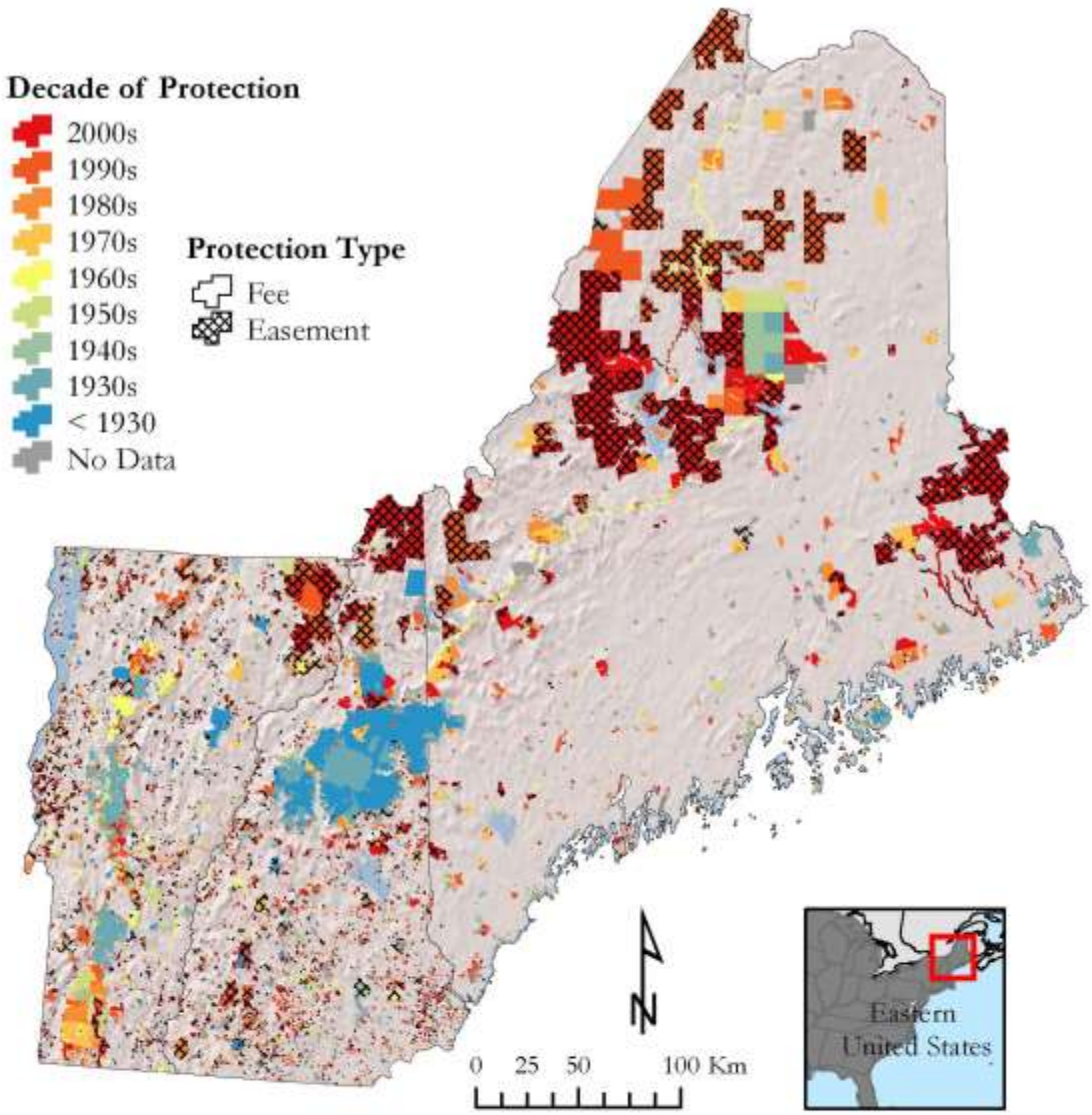


Table 2. Summary of protection by decade for each of three states in New England. Columns show both number of hectares protected and percent of total area protected by decade. Decades during which our data show no protection activity are omitted. Note that our data are calculated on an annual basis, as shown in Fig. 1, but for brevity data are summarized here by decade.

	Maine		New Hampshire		Vermont		Total	
Decade	hectares	%	hectares	%	hectares	%	hectares	%
1800s	-	0%	10,828	2%	-	0%	10,828	0%
1840s	402	0%	-	0%	-	0%	402	0%
1890s	-	0%	215	0%	7	0%	222	0%
1900s	171	0%	432	0%	5,502	1%	6,105	0%
1910s	14,431	1%	140,712	21%	12,985	2%	168,128	6%
1920s	3,788	0%	56,535	8%	4,427	1%	64,750	2%
1930s	42,768	3%	88,323	13%	75,744	14%	206,834	8%
1940s	48,013	3%	12,635	2%	8,416	2%	69,064	3%
1950s	28,422	2%	9,639	1%	54,696	10%	92,757	3%
1960s	27,378	2%	7,305	1%	31,846	6%	66,529	2%
1970s	87,804	6%	21,167	3%	33,867	6%	142,838	5%
1980s	79,522	5%	49,930	7%	39,658	7%	169,110	6%
1990s	446,002	29%	60,940	9%	127,458	24%	634,400	23%
2000s	655,810	42%	141,230	21%	85,226	16%	882,267	32%
Sub-total	1,434,510	93%	599,891	89%	479,833	89%	2,514,234	91%
Year unkonwn	110,060	7%	74,342	11%	58,889	11%	243,291	9%
Total	1,544,570	100%	674,233	100%	538,722	100%	2,757,525	100%

Figure 3. Land protection status by decade according to the current GAP status: 1 - natural state is maintained despite natural disturbances; 2 - natural state is maintained with some provision for management against natural disturbances; and 3 - extractive uses are allowed. Current GAP status may not have been in place at time of protection. Protected areas for which no GAP status is assigned are excluded.

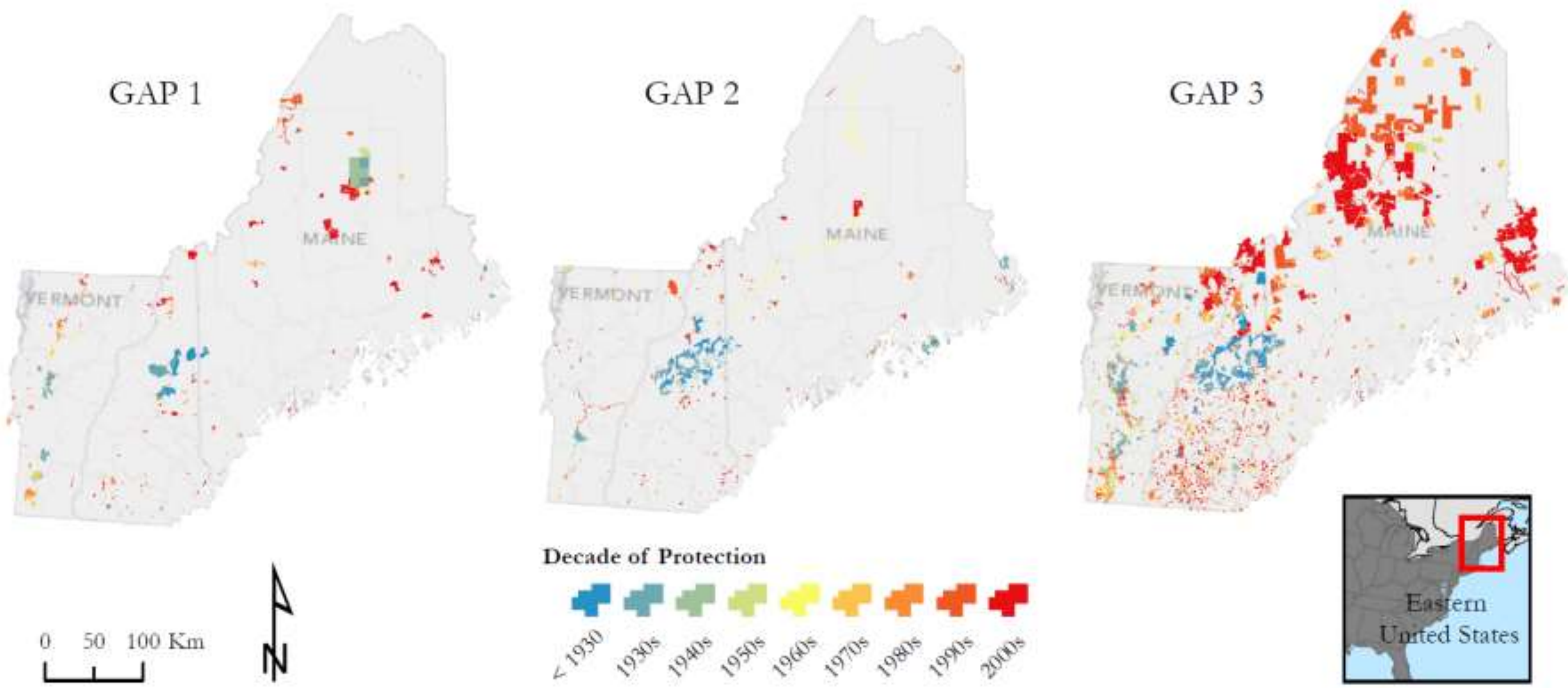
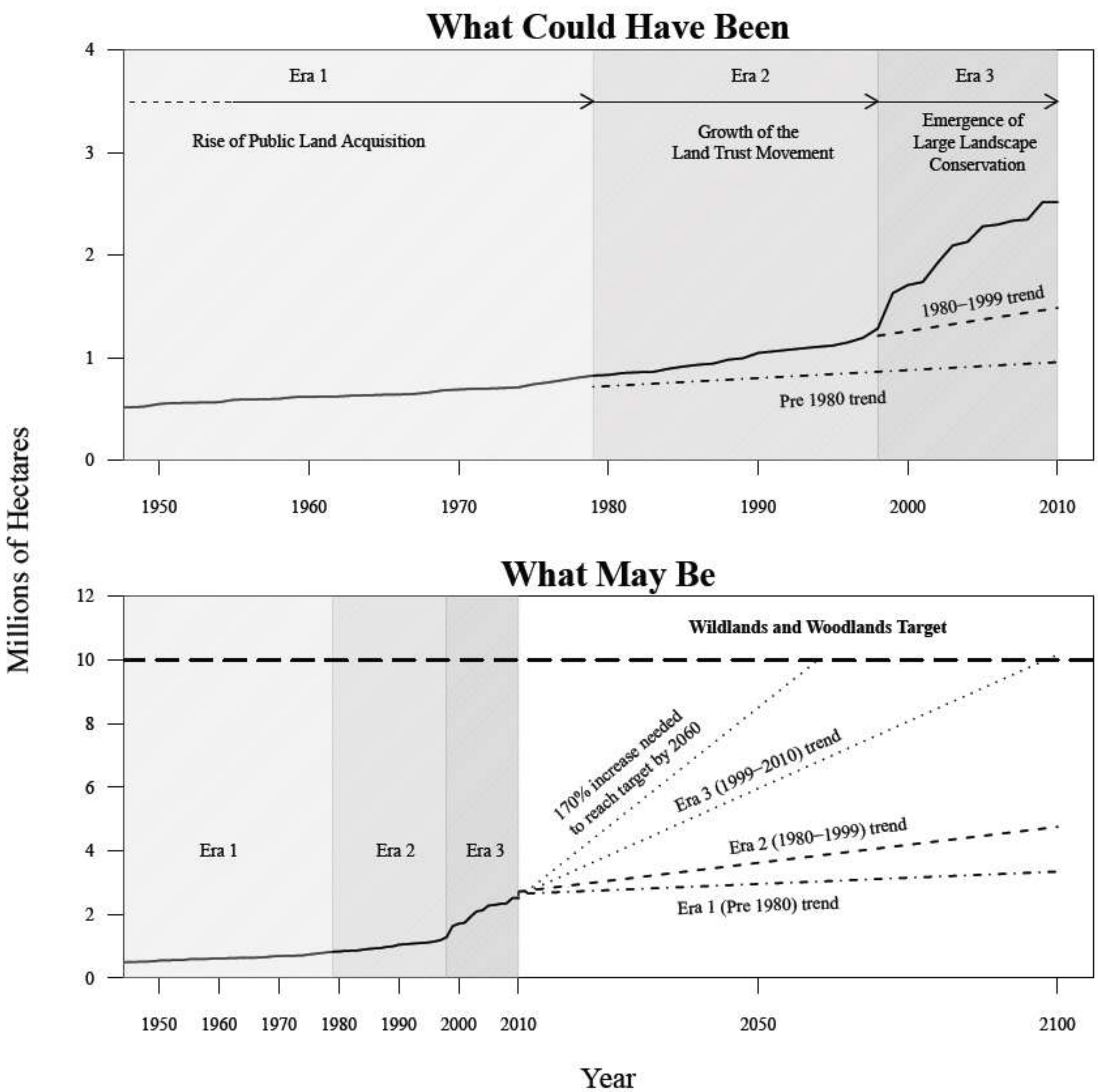


Table 3. Summary of rate of protection for each conservation era and future projections based on past trajectories. Projections are based on linear extrapolations of each of the three eras. *Predicted area* and *% Different* columns indicate what could have been expected in 2010 if the trajectories from previous eras had continued. *Projected* years column indicates the years required to reach the W&W target using the projections from each previous era.

					Era-based projections		
Conservation Era	Length of era (years)	Area protected (ha)	Average rate of protection (ha/yr)	Rate of protection of study area (% of area/yr)	Predicted area protected in 2010 (ha)	% Different from actual	Projected years to reach W&W target
Public Land Acquisition (1800-1979)	180	820,134	4,556	0.04%	959,556	-62%	1,179
Land Trust Movement (1980-1998)	19	459,228	24,170	0.19%	1,487,748	-41%	381
Large Landscape Conservation (1999-2010)	12	1,230,504	102,542	0.81%	-	-	79
Year unknown		243,291					
Total	211	2,757,525	13,069	0.10%			

Figure 4. Comparison of actual and projected area of PAs as of 2010 based on extrapolated conservation trajectories for Eras 1 and 2 (top graph). Difference between actual and projected are presented in Table 3. Bottom graph shows projected cumulative area in PAs based on the trends of Eras 1 through 3, as well as the trajectory needed to meet the Wildlands and Woodlands goal. Both graphs exclude PAs for which the year of establishment is not known.



Note: Figures 2 and 3 are intended to be produced in color, both on the web and in print.