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Large landscape conservation in a mixed ownership region: Opportunities and barriers for putting the pieces together

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ABSTRACT

The spatial overlap between large landscape conservation designs and existing land protections is not always clear, especially in regions where private ownerships and small parcel sizes are typical. In this case study, we used geospatial analyses to compare a new state-level conservation design, Vermont Conservation Design, with formally protected lands in Vermont, USA. We found that roughly one third of the design's highest priority landscape-level targets have already been met through formal land protections. Public agencies are the primary interest holders for a majority of protected highest priority interior forest block and connectivity block targets. Conversely, private nonprofits play an important role as the dominant interest holders in protected riparian connectivity and highest priority surface water and riparian area targets, which are also the most underrepresented among protected landscape-level targets in the state. There was notable variation in highest priority design targets met via formal land protections at the county level. Some counties containing large public or former corporate timberland tracts also display relatively high percentages of design targets protected, whereas those dominated by family forest owners generally have lower percentages of protected targets. Our study suggests that achievement of large landscape conservation designs will occur more readily in landscapes containing large blocks of public or former timber industry forestlands. Our results also highlight strategies that could focus efforts to fulfill large landscape conservation initiatives in places where mixed private and public land ownership is the norm. Such strategies include continued support for collaboration between public and private partners in conservation; planning for the capacity to respond quickly to large, one-time land sales that are important design targets; increased support for nonprofits in acquiring protections for underrepresented surface waters and riparian connectivity targets; and an increased focus on the protection of low elevation targets in large landscape conservation designs.

1. Introduction

Roughly 12.5% of the Earth's land base has been set aside in formally protected areas (Joppa and Pfaff, 2009); however, climate change impacts, rapid biodiversity losses, and increasing human demands on the planet's limited resources have generated growing recognition of the need for a new phase of large landscape, spatially and temporally explicit conservation planning efforts that integrate dynamic human and natural systems and consider adaptive responses to global threats (Aycrigg et al., 2016; Baldwin et al., 2018; Heller and Zavaleta, 2009; Maiorano et al., 2006; National Academies of Sciences, Engineering, and Medicine, 2016; Network for Landscape Conservation, 2018; Pressey et al., 2007; Trombulak and Baldwin, 2010). To this end, large landscape conservation (also termed "landscape-scale conservation" or "landscape conservation") has emerged as one response in the conservation community. Many large landscape conservation initiatives seek to link and steward sizable areas of habitat that represent a wide range of biophysical conditions but form an ecologically meaningful unit; some also attempt to protect local communities and livelihoods for the future or plan for long-distance species migrations and climate change impacts. To accomplish this, these visions typically promote collaboration or a shared vision among stakeholders that extend beyond traditional legal and organizational boundaries; some initiatives also lack spatially-explicit borders (McKinney et al., 2010; Network for Landscape Conservation, 2018). Examples of large landscape conservation initiatives include the Yellowstone to Yukon Conservation Initiative (2019), which spans the U.S.-Canadian border and targets an area for habitat connectivity almost as large as California (McKinney

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et al., 2010); the Landscape Conservation Cooperatives (LCCs), a network of 22 ecoregional groups for North America, spearheaded by the U.S. Department of the Interior in recognition of the need for national leadership in large landscape conservation (National Academies of Sciences, Engineering, and Medicine, 2016); Regional Conservation Partnerships (RCPs), which in New England, USA are public-private partnerships focused on advancing land and/or natural resource protection in a multi-jurisdictional area (Labich et al., 2013); and the Wildlands and Woodlands Initiative, which aims to keep 70% of the U.S.'s New England states in forest, with 10% of that subset as wildland reserves and 90% as multi-use woodland while also protecting agricultural resources and local communities' livelihoods for the future (Foster et al. 2010 & 2017; Labich, 2015).

Large landscape conservation faces a number of challenges, however. Planning for variable ecological considerations across big areas, the matrix and scale of private and public lands that must be considered, the financial, political, and organizational capacities of partners to undertake such initiatives, and the dynamics, variety, and long-term objectives of stakeholders may present multifaceted difficulties (Baldwin et al., 2018; McKinney et al., 2010; Network for Landscape Conservation, 2018; Powell, 2010; Scarlett and McKinney, 2016; Tabor et al., 2014; Trombulak and Baldwin, 2010; Wyborn, 2014). A number of large landscape conservation initiatives also occur in landscapes on which large parcel sizes and/or public holdings are relatively common. This is true of the Northwest Forest Plan (Franklin and Norman Johnson, 2014), the High Divide Collaborative (2019), the Blackfoot Challenge (2019), the Tahoe Regional Planning Agency (2019) and others; strategies developed for such places may not be transferable to areas where small parcel size and private land ownership are the norm. Finally, it is unclear as to how realistic some large landscape conservation initiatives are, and—when spatially explicit—how well they overlap with pre-existing land protections. As such, there is a need for evaluation of the compatibility and potential barriers to implementing a given conservation design[1] within certain ownership matrices.

The northeastern United States presents a useful context for examining the compatibility of new large landscape conservation designs with existing land protections, given the preponderance of private ownerships, as well as a long history of formal land protection through public acquisitions and easements in the region (Lilieholm et al., 2010; Meyer et al., 2014; Natural Resources Council of Maine, 2013). In the Northeast, 80% of forests are privately owned, and 70% of this subset are held by families and individuals, collectively termed "family forest owners" (Thompson et al., 2017). This pattern of land ownership is largely due to European settlement history of the United States. Beginning in the late 1700s, the concept of public domain resulted in greater reservation of lands west of the Appalachians by the federal government, while in the east, lands were granted to individual settlers early on, with the government later buying back some parcels (Fairfax et al., 2005). As a result, eastern parts of the country have far fewer large federal ownerships than many western areas (Fairfax et al., 2005; Jenkins et al., 2015; Smith et al., 1997), and 46.6% of the land bases of the eleven western-most states in the U.S. are owned by the federal government, compared with just 4.2% of all other states (Vincent et al., 2017). Additionally, 70% of forests in the western U.S. are public, whereas in the east, only 19% of forests are public (U.S. Forest Service, 2014) (Fig. 1). The so-called Northern Forest—spanning the states of New York, Maine, New Hampshire, and Vermont—is 10.4 million hectares in size, of which 8.9 million hectares are privately owned (Daigle et al., 2012). The prevalence of small, private parcel ownership in the Northeast may make landscape-level conservation strategies that are working elsewhere more difficult to apply.

Moreover, systematic changes to land protection strategies in the United States over the past 400 years have resulted in "conservation mosaics" on the landscape, with multiple actors employing different tactics and objectives to protection. Changing paradigms about why to protect land—from defense; to historic value, beauty, and recreation; to the prevention of natural disasters; to opportunistic economics; to community values; to biodiversity—have also shaped the evolution of conservation strategies and the selection of parcels that are today's protected lands (Fairfax et al., 2005).

Large landscape conservation is receiving growing international attention, and the number of working partnerships and examples continue to increase (Baldwin et al., 2018; McKinney et al., 2010; Network for Landscape Conservation, 2018). However, it is difficult to find studies that quantify how well new conservation designs are meeting their targets, especially in regions dominated by private land ownership. For this study, we present findings from a geospatial analysis that compares currently protected lands in Vermont, USA with a new large landscape conservation design collaboratively developed by state agencies and conservation organizations (hereafter referred to as *Vermont Conservation Design*). Since private ownerships represent a disproportionate share of land holdings in the state, we hope to shed light on how a new large landscape conservation design and existing land protections overlap and where they diverge. Our results can inform future large landscape conservation efforts by pinpointing the locations in which gaps and overlaps are likely to occur, and by suggesting possible strategies for the future adoption of conservation designs in mixed-ownership regions.

2. Methods

2.1. Study area

Located in the northeastern United States, Vermont has 2.4 million hectares of land. Like most of New England, it has also undergone dramatic land use changes during the past 250 years. First home to the Abenaki and Mahican people, Vermont was heavily logged, cultivated, and grazed by European settlers from the 1760s to the 1840s. By the 1880s, growing western opportunities, falling local profit margins, and declining crop yields resulted in large-scale farm abandonment and eventual reforestation (Albers, 2000). Today, Vermont is home to about 626,000 people and is one of the most rural states in the U.S. (U.S. Census Bureau, 2018). The state is 76% forested, of which 20% is publicly owned, 19% is controlled by corporations and other entities, and the remaining 61% is held by private landowners (U.S. Forest Service, 2016). A majority of private forest landowners in Vermont own < 20.2 ha, but the remaining individuals control 77% of all forests in the state (Butler et al., 2014). Therefore, in addition to working predominantly with private landowners, Vermont's conservation community faces the challenge of reaching out to both large numbers of people who own a small amount of land and a small number of people who own larger parcels.

2.2. Compiling a spatial database of Vermont's protected lands

Vermont does not have a single, up-to-date, spatially accurate database of its currently protected lands. To address this, we combined three different protected lands datasets and then corrected for all overlapping polygons to create a useable hybrid product, "New Hybrid Protected Lands Layer for Vermont Conservation Design Analysis (February 2019)" (hereafter referred to as the *hybrid protected lands layer*). Our input datasets consisted of Vermont Land Trust's (VLT) database of protected lands, current as of February 2019 (obtained through private correspondence with VLT's Jon Osborne); The Nature Conservancy's (TNC) Secured Areas database, based on PAD-US 2015 with some TNC-specific updates through 2018 (obtained through

[1] We recognize that the term "conservation design" has multiple valid meanings, but for the purposes of this paper, we define conservation design to mean *any large landscape conservation initiative with spatially-explicit targets or boundaries*.

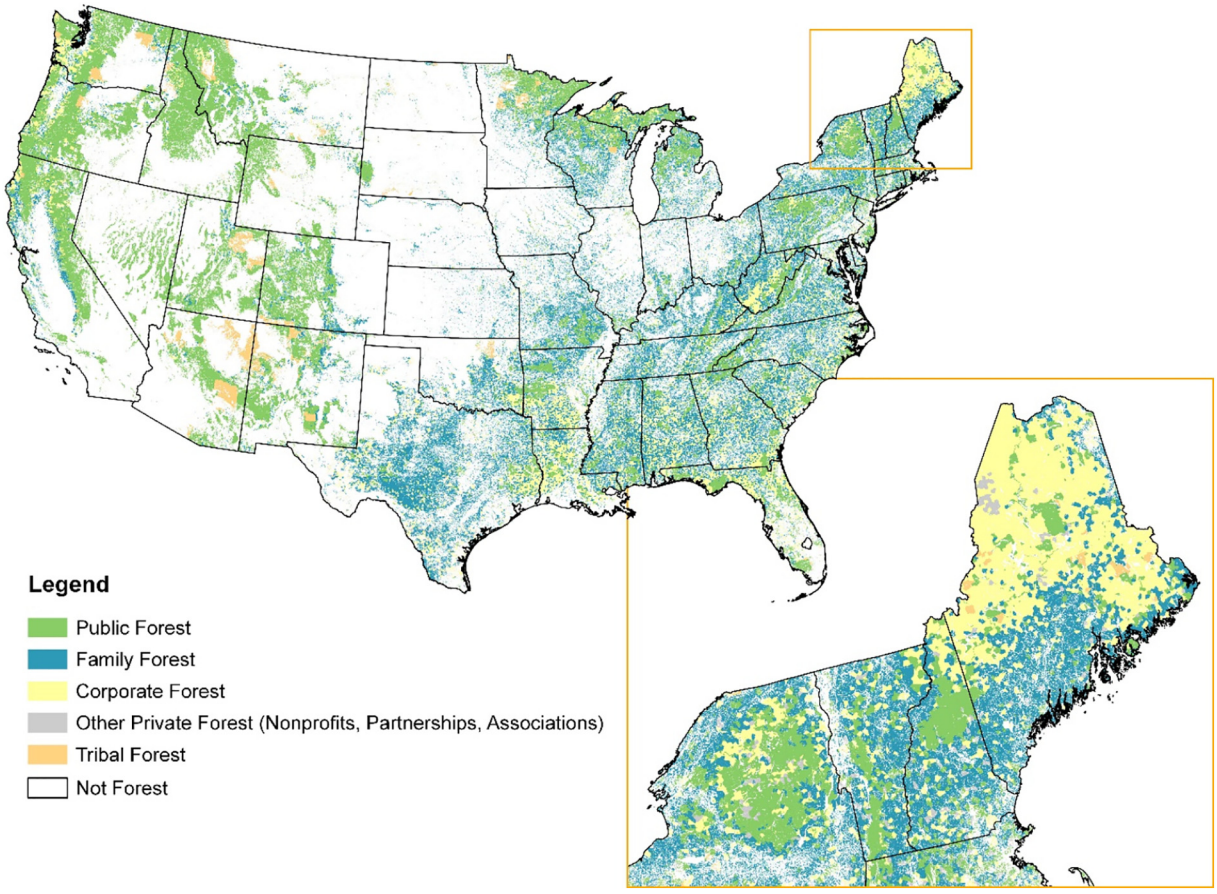


Fig. 1. Forest ownership in the contiguous United States, 2014. In the western United States, a majority of forests are under public ownership, while eastern forests tend to be privately owned. In the Northeast, northern Maine is dominated by private corporate ownership, while in other parts of the Northern Forest—spanning New York, Maine, New Hampshire, and Vermont—family forests and large tracts of public forests are more common. (Map by Carolyn D. Loeb; Dataset: Hewes et al., 2017). (For interpretation of the references to colour in this and all other figures, the reader is referred to the web version of this article.)

private correspondence with TNC's Dan Farrell); and the Vermont Center for Geographic Information's (VCGI) publicly available Protected Lands Dataset, March 2017 Edition (2018).

The VLT and TNC datasets were used as the scaffolding for our hybrid protected lands layer, while VCGI's dataset was only used when it contained information not available elsewhere. All datasets listed information about protected areas' fee owners, interest holders (agencies holding an easement, covenant, or conservation restriction on the property), or both. However, data on fee ownership for conserved parcels was patchy across input datasets, so our analyses focused on the role of interest holders in parcel protection. When both a fee owner and an interest holder were listed for a parcel, the interest holder was designated as the primary protecting agency in our output hybrid protected lands layer. VLT and VGCI's datasets pre-defined agencies as primary, secondary, or tertiary interest holders where multiple parties were listed. In TNC's dataset, interest holder type (federal, state, nonprofit, etc.) was available and was referenced when a single cell listed multiple interest holders' names (for example, "The Nature Conservancy with the Vermont Housing and Conservation Board"). When no interest holder was listed for a property, the fee owner was assumed to be the primary protecting agency. Thus, our analyses highlight the roles of current, primary interest holders in land protection (hereafter referred to as *primary protecting agencies*) and cannot do justice to the roles that fee owners play in conservation, nor to the complex temporal and relational dynamics of protection that involve multiple fee or interest holders interacting on a parcel in space and time.

Although our hybrid product is an improvement over other known datasets for our purposes, it still does not account for all protected lands in Vermont. Specifically, our state-level analyses underrepresent parcels conserved by the Upper Valley Land Trust (UVLT) by about 8500 ha (equivalent to 1.4% of all protected lands in Vermont), since the UVLT dataset was not publicly available at the time of our study. UVLT operates in Orange, Caledonia, and Windsor Counties in the state. We were able to belatedly acquire this missing data for Orange County, given that it was a notable outlier in our county-level analysis results, but UVLT's dataset is not contained in our hybrid protected lands layer nor in our other study results. We were also unable to analyze temporal changes in protections in our analyses, since our input datasets lacked consistent information about parcel protection dates. The hybrid protected lands layer may also contain other errors inherited from its parent datasets, although the source data are generally regarded as the best available. Despite these limitations, the hybrid product we developed provides an important resource for gauging the degree of general agreement between currently protected lands and Vermont Conservation Design for the vast majority of Vermont (See Appendix A: Supplementary Data for a link to the shapefile of our hybrid protected lands layer and detailed metadata regarding its creation). PAD-US 2.0 was released in 2018 and may be used for similar analyses; however, we are confident that our hybrid product is superior for the purposes of our study, due to Vermont-specific VLT and TNC improvements to parent datasets, combined with our work to correct hundreds of overlapping polygons for highly accurate area calculations. We used ESRI's ArcGIS Pro software (2018) for all data management and geospatial analysis.

2.3. Vermont Conservation Design

Vermont Conservation Design (VCD), completed for landscape-level targets in 2015, is a spatially-explicit large landscape conservation vision developed for the entire state. It is the result of a multi-year, collaborative partnership between the Vermont Fish & Wildlife Department, Vermont Land Trust, and other partners (Vermont Agency of Natural Resources, 2018). Another spatially-explicit conservation design—The Nature Conservancy's Resilient Sites for Terrestrial Conservation in Eastern North America—also includes Vermont (Anderson et al., 2016), and there is quite a bit of overlap in identified targets between the two visions for the state (personal communication with VLT's Elizabeth Thompson). For this study, we used shapefiles of Vermont Conservation Design landscape-level targets received from the Vermont Fish & Wildlife Department in Fall 2018. Input layers included highest priority interior forest blocks, highest priority connectivity blocks, physical landscape diversity blocks, highest priority surface waters and riparian areas, and riparian connectivity. We did not include wildlife road crossings in our analyses, since they do not typically fall under protected lands status, and because ownership may be unclear or belong to many parties.

To standardize inputs, all VCD and hybrid protected lands layer data were clipped to the shape of Vermont. The individual landscape elements listed above were then merged to create a single shapefile of all landscape-level targets for the analyses. For individual landscape element assessment, the input layers were used without further modification, except for those described in our methods.

2.4. Examining the overlap between a new vision and protected lands

We excluded all waterbodies except for small streams from the design and hybrid protected lands layers prior to analysis, since inclusion would have biased county-level results around Lake Champlain, a 1269 km^2 lake on the western boundary of the state, and since the data on waterbody status and primary protecting agency may be unclear or unavailable. Thus, our analyses do not include the areas associated with ponds, lakes, and rivers even if they occur on protected lands. We also introduced county boundaries into our hybrid protected lands layer prior to running the analyses so that we could look for regional variation in results (and since comparative county-level metrics are readily available), even though counties do not constitute a form of governance in Vermont.

To examine the overlaps between formally protected areas and Vermont Conservation Design, we spatially intersected our hybrid protected lands layer with the design's highest priority landscape-level targets. We did this for all highest priority landscape-level targets combined, as well as for each individual highest priority landscape element listed above. The output in each instance was a layer that displayed all overlaps between each highest priority design target and currently protected lands, excluding waterbodies and subdivided by county. We then used the program Tableau (2019) to visually explore data and to generate cross tabulations of hectares of design targets met at the county level and by primary protecting agency type.

2.5. Statistical analyses

Factors potentially influencing the levels of overlap between formally protected lands and Vermont Conservation Design highest priority design targets were examined by calculating county-level metrics, including median household income, mean population density per square mile, mean elevation above sea level, mean conservation design target elevation above sea level, and mean protected design target elevation above sea level. Median county household income and mean county-level population density per square mile were determined for 2014–2018 and 2010, respectively, based on U.S. Census Bureau data (2019). We utilized ESRI ArcGIS Pro's (2018) zonal statistics as table tool to calculate a mean elevation above sea level for each county, as well as for highest priority design targets and protected targets at the county level (excluding waterbodies) using a 2002 30-meter Digital Elevation Model (DEM) (Vermont Center for Geographic Information, 2019). The zonal statistics as table tool was also used to obtain the mean elevation above sea level across all formally protected lands in the state, regardless of their inclusion in the design; the mean elevation above sea level of all conservation design highest priority targets in the state, regardless of protection; and the mean elevation above sea level of all protected highest priority targets in the state (excluding waterbodies). We tested for correlations between county-level attainment of design targets and the abovementioned county-level metrics using Pearson's correlation coefficient. In cases where data did not meet the assumptions of this test, the non-parametric Spearman's Rho test was run instead. We used JMP 15 (JMP, 2019) for these analyses and an alpha of 0.05 for significance.

3. Results

3.1. How much of the state is a large landscape design target?

About two thirds of Vermont's land base (67.7% or 1.61 million hectares) is a highest priority landscape-level Vermont Conservation Design target of some kind. Such a result is perhaps not as surprising as it first appears, since although the identification of coarse-filter targets was based on detailed selection criteria (Vermont Agency of Natural Resources' BioFinder/Vermont Conservation Design Team, 2016), the overarching goal of the design's steering committee was to select “the set of highest-priority features that collectively gave [the committee] high confidence in maintaining an ecologically functional landscape… without any political, practical, or arbitrary cutoffs” (private correspondence with Bob Zaino, Vermont Fish and Wildlife Department). With regards to individual landscape elements, we calculated that 42.6% of Vermont is a highest priority interior forest block target; 47.5% is a highest priority connectivity block target; 16.2% is a physical landscape diversity block target; 12.3% is a riparian connectivity target, and 18.5% is a highest priority surface waters and riparian areas target. There is significant spatial overlap between some landscape elements. Fig. 3 depicts design target totals in hectares for each landscape element at the state level and the progress that has been made by different primary protecting agency types towards meeting targets via protected lands.

3.2. How much land is already conserved?

Our data indicates that Vermont has over 600,000 ha of formally protected lands, which is about one quarter (25.6%) of the state's land base. The three largest interest holders in protected lands in Vermont are the federal government, the state government, and private nonprofit organizations. Across all protected areas, the primary protecting agency type (interest holder) is 30.5% federal (185,609 ha); 30.5% state (185,850 ha); 35.4% nonprofit (215,408 ha); 3.6% town (22,079 ha); and 0.01% tribal (65 ha). 0.02% (103 ha) of protected lands in our dataset did not have a primary protecting agency listed.

3.3. State-level analysis results

Eighty seven point one percent of currently conserved lands are also highest priority landscape-level design targets. Put in another way, Vermont's protected lands account for about one-third (32.9%) of all identified highest priority design targets, which is about one fifth (22.3%) of Vermont's land base, or approximately 530,000 ha of land (Fig. 2). State-level results for individual landscape elements reveal that a relatively high percentage of highest priority interior forest block and connectivity block targets have been formally protected, while highest priority riparian connectivity and surface water and riparian area

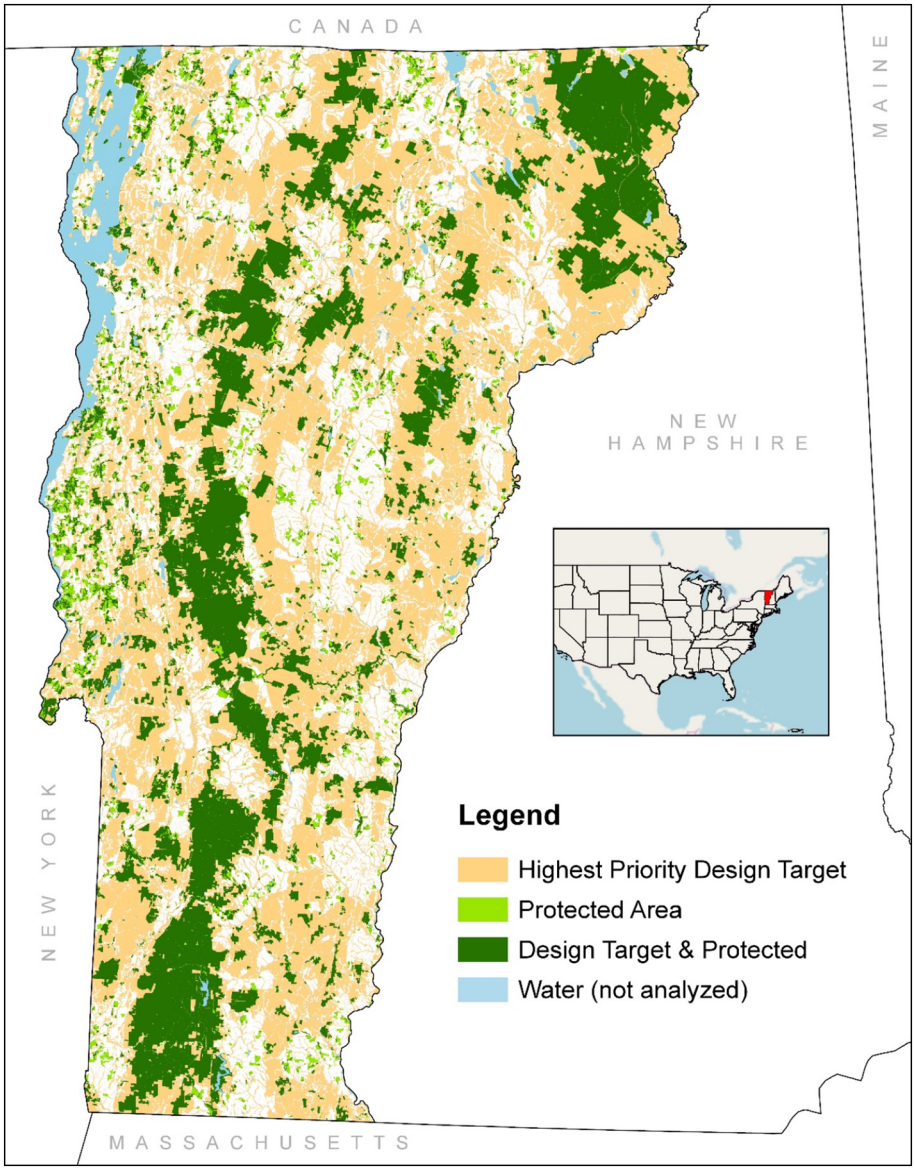


Fig. 2. Spatial overlap between highest priority landscape-level Vermont Conservation Design targets and protected lands. Areas of overlap are shown in dark green (Map by Carolyn D. Loeb; Datasets: New Hybrid Protected Lands Layer for Vermont Conservation Design Analysis (February 2019); Vermont Conservation Design layers received from the Vermont Fish & Wildlife Department in 2018).

targets are the least protected (Fig. 3).

Nonprofit organizations are the primary protecting agency type for the largest percentage of conserved highest priority riparian connectivity and surface water and riparian area targets. Conversely, federal and state agencies are the dominant interest holders in highest priority interior forest blocks, connectivity blocks, and—to a lesser extent—physical landscape diversity blocks (Fig. 3). Since our analyses focused on the role of interest holders in formal land protection, it is not surprising that private landowners and tribal categories are the primary interest holders in < 0.1% of protected design targets, and thus are not reported in our study results.

3.4. County-level trends

Although counties do not constitute a form of governance in Vermont, we conducted county-level analyses to highlight regional variation in our results. Based on our analyses, Bennington and Essex Counties rank highest in Vermont at current attainment of combined highest priority landscape-level design targets, while Orange County ranks lowest (Table 1). There was notable variation at the county level in terms of individual landscape element design targets met via protected lands, with landscape elements of different types protected at relatively even rates in some counties, while in other counties, some elements have been protected at higher rates than others (Fig. 4). County-level attainment of highest priority protected design targets relative to county-level identified targets averaged 31.0% across all Vermont counties.

There was no relationship between county-level progress towards meeting highest priority design targets and median county-level household income ($p = .25$), county population density per square mile ($p = .75$), mean county elevation ($p = .39$), mean design target elevation ($p = .30$), or mean protected design target elevation ($p = .13$). Based on our zonal statistics analysis, the mean highest priority conservation design target elevation (regardless of protected status) occurs at 420 meters above sea level (m.a.s.l.), the mean protected lands elevation (regardless of inclusion in the design) occurs at 493 m.a.s.l., and the mean protected highest priority target elevation occurs at 527 m.a.s.l. at the state level.

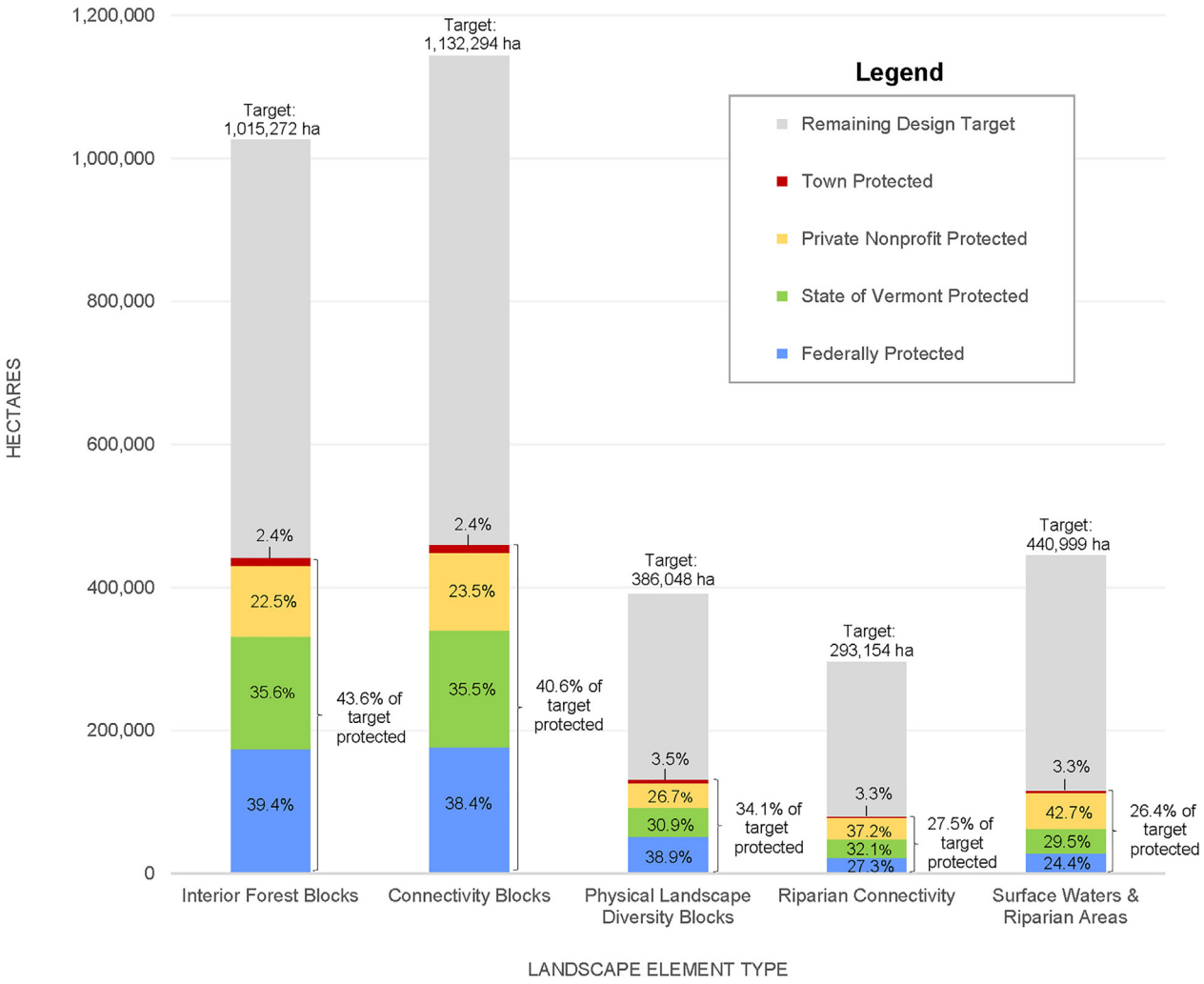


Fig. 3. State-level targets for highest priority landscape design elements and percentages of each element that are formally protected by primary protecting agency type. Numbers within colored bars display the proportion of protected lands conserved by each primary protecting agency type.

Table 1
Targeted hectares of all highest priority landscape-level design elements combined and current levels of attainment via protected lands, viewed through a county-level lens.

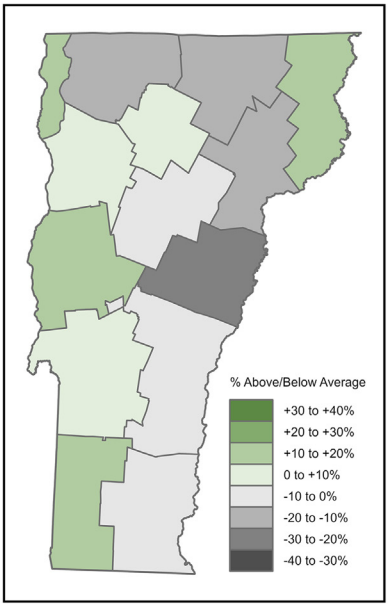
County name	Total county-level highest priority design hectares targeted	Percent of county-level design targets protected
ESSEX	161,389	55.0%
BENNINGTON	137,490	54.6%
ADDISON	131,873	43.8%
RUTLAND	177,018	37.3%
LAMOILLE	87,297	35.9%
CHITTENDEN	82,952	30.7%
WINDHAM	133,038	26.1%
WINDSOR	159,795	25.8%
WASHINGTON	116,994	25.7%
FRANKLIN	87,815	22.4%
ORLEANS	109,567	21.5%
GRAND ISLE	10,381	20.5%
CALEDONIA	114,411	19.7%
ORANGE[a]	102,216	14.9%

[a] Orange County results include the full Upper Valley Land Trust dataset which was unavailable for the state-level analysis.

4. Discussion

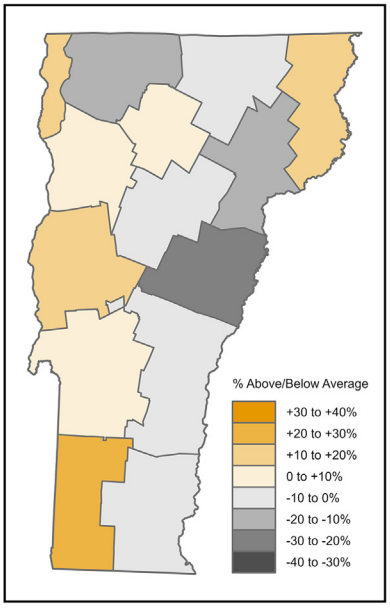
Temporal trends in Vermont conservation were outside of the scope of our analyses; however, since trends in protection over time have significant implications for currently conserved lands and the adoption of large landscape designs, we consider some of the state's history here (also examined by Meyer et al. 2014 & 2015). Our analyses reveal that the federal government is the primary protecting agency for 34.4% (182,295 ha) of all conserved highest priority design targets in Vermont. Most of this area is protected by the U.S. Forest Service, which currently protects about 162,000 ha of highest priority targets, or roughly 10% of the full conservation design (Table 2). Nationally, the federal government's land acquisition activities peaked in the late 1800s and early 1900s (Fairfax et al., 2005; Lilieholm et al., 2010; Meyer et al., 2014), and the U.S. Forest Service's greatest land protection efforts largely occurred between 1905 and 1987 (Williams, 2005). Nevertheless, since the creation of the Green Mountain National Forest in 1932, the federal government has continued to acquire land in Vermont, with U.S. Forest Service lands alone totaling 64,749 ha in 1937, 89,030 ha in 1959, 148,282 ha by 1997 and 161,698 ha in 2010 (McGrory Klyza and Trombulak, 2015). While these continued expansions do not fit with the national trend, they are somewhat more in line with other eastern national forests that have seen gradual reassembly via sales from willing private parties (Shands and Healy, 1977). Similarly, our analyses indicate that the State of Vermont currently protects

Highest Priority
Interior Forest Blocks



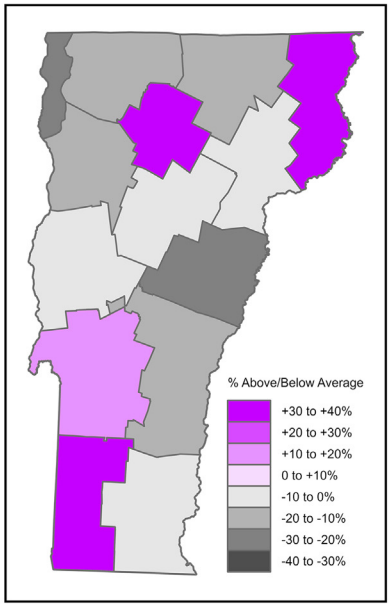
a. An average of 41.28% of highest priority interior forest block targets have been formally protected across all Vermont counties. Individual county-level protection rates relative to this average are shown above.

Highest Priority
Connectivity Blocks



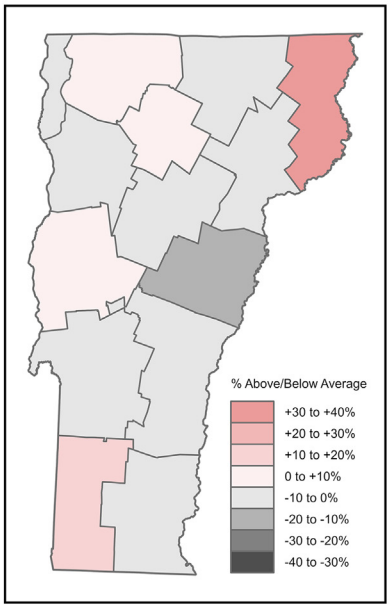
b. An average of 38.87% of highest priority connectivity block targets have been formally protected across all Vermont counties. Individual county-level protection rates relative to this average are shown above.

Highest Priority Physical
Landscape Diversity Blocks



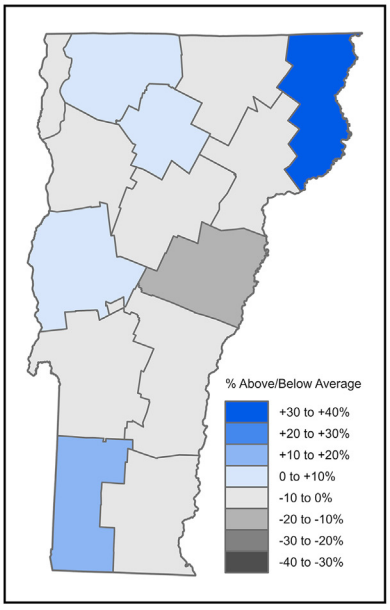
c. An average of 36.62% of physical landscape diversity block targets have been formally protected across all Vermont counties. Individual county-level protection rates relative to this average are shown above.

Highest Priority
Riparian Connectivity



d. An average of 26.43% of riparian connectivity targets have been formally protected across all Vermont counties. Individual county-level protection rates relative to this average are shown above.

Highest Priority Surface Waters
& Riparian Areas



e. An average of 25.60% of highest priority surface water and riparian area targets have been formally protected across all Vermont counties. Individual county-level protection rates relative to this average are shown above.

Vermont Counties
Reference Map

(caption on next page)

Fig. 4. Variation in the protection of individual landscape element design targets under Vermont Conservation Design as seen through a county-level lens. In some Vermont counties, different landscape elements have been relatively evenly protected, while in other counties, certain elements stand out as better or worse protected, as compared to average protection rates. Current protection rates for each county were analyzed by dividing the hectares of protected lands that are highest priority design targets for a county by that county's total design-targeted hectares. All counties' protection rates were then averaged to create a baseline for cross-county comparison. (Map by Carolyn D. Loeb; Datasets: Tableau (2019) was used to cross-tabulate and compare overlapping hectares at the county level between the New Hybrid Protected Lands Layer for Vermont Conservation Design Analysis (February 2019) and input Vermont Conservation Design layers received from the Vermont Fish & Wildlife Department in 2018).

Table 2
Vermont's largest primary protecting agencies in conserving highest priority design targets. All agencies conserving > 5000 ha are listed below.

Primary protecting agency type & name	Protected targets (hectares)
FEDERAL	
US Forest Service	162,232
US Fish & Wildlife Service	13,404
STATE	
VT Forests, Parks and Recreation	127,073
VT Department of Fish & Wildlife	40,208
PRIVATE NONPROFIT	
Vermont Land Trust	100,588
The Nature Conservancy	17,453
The Nature Conservancy with the Vermont Housing and Conservation Board	11,698
Green Mountain Club	6876

33.4% (177,326 ha) of all conserved highest priority design targets, with the Vermont Department of Forests, Parks and Recreation (VT FPR) protecting the most design-targeted lands of any state agency, at over 120,000 ha (Table 2). State-conserved lands totaled 28,327 ha in 1940, 136,299 ha by 1997 and 192,490 ha as of 2013 (McGrory Klyza and Trombulak, 2015). Throughout the past century, both federal and state governments have received occasional funding spurts—such as via the Land and Water Conservation Fund (LWCF) of 1964—that allowed for periods of more intense acquisition (McGrory Klyza and Trombulak, 2015).

Other authors have noted the acceleration of land protection in the Northeast beginning in the 1980s, and have concluded that the use of conservation easements and the involvement of nonprofits have been a major factor in that trend (McGrory Klyza and Trombulak, 2015; Meyer et al., 2014). In Vermont, funding for the LWCF declined in the 1980s and the state responded by establishing the Vermont Housing and Conservation Board (VHCB). VHCB, a public entity, has since aided both public and private nonprofit organizations with funding for conservation. Groups like Vermont Land Trust, the Nature Conservancy, and the Green Mountain Club have all been direct beneficiaries. Other federal initiatives like Forest Legacy (1990), have also contributed public funding for conservation to private nonprofits (McGrory Klyza and Trombulak, 2015). Our study illustrates that in Vermont, private nonprofits collectively conserve 28.9% (153,280 ha) of protected highest priority design targets, despite their much more recent emergence as an agent in land protection. The Vermont Land Trust (VLT), founded in 1977 (Vermont Land Trust, 2020), helped conserve 56,000 ha in Vermont from 1977 to 1997 alone (McGrory Klyza and Trombulak, 2015)—and according to our analysis, VLT currently protects over 100,000 ha of highest priority design targets (Table 2). The Green Mountain Club (GMC), a small private nonprofit, began conserving land in 1987. GMC now holds an interest or fee ownership on about 8500 ha of land in the state (Green Mountain Club, 2019 and 2020), > 6800 ha of which are highest priority design targets (Table 2). As with other regions, this example illustrates both the important temporal dynamics of land protection and also that collaboration within conservation has been central to the history of Vermont's protected lands, although we did not have sufficient data to quantify these trends.

The importance of large, one-time windfalls of former timber industry lands to regional conservation initiatives is a trend that has been observed broadly across the US as vertically-integrated timber companies have divested ownerships over the past two decades (Bliss et al., 2010; D'Amato et al., 2018; Meyer et al., 2014). From 2001 to 2007 alone, the timber industry sold off > 10 million hectares of former industry lands across the country (Bliss et al., 2010). In Vermont, over 53,000 ha of these industrial forestlands were purchased from the Champion International Corporation in 1998 by conservation organizations and state and federal agencies to provide permanent protection in various forms (Vermont Agency of Natural Resources, 1999). The fact that these sales are unique opportunities for large scale conservation is demonstrated in our analyses, as the county with the highest level of progress towards meeting design goals (Essex County, Fig. 4) also contains a majority of the former industrial timberlands in the state. Our calculations indicate that these purchases have collectively conserved more than a third of Essex's identified county-level design targets (Table 1). Nevertheless, in the Northeast, commercial ownership of working landscapes appears to have stabilized relative to the large sell-offs that happened in the 1990s and 2000s (Meyer et al., 2014), so future opportunities of this type in our study area may be rare. Additionally, such acquisitions require conservation organizations and partners to have the capacity to respond to unexpected conservation opportunities (Fairfax et al., 2005), which has proven challenging in recent years with declining government support for such purchases (Meyer et al., 2014).

Federal, state, and private nonprofit agencies have surprisingly even shares in protecting highest priority design targets in our analysis results (Fig. 3), but examination of conservation history in the region points both to the complex partnerships at work and to the varying importance of different agencies over time. Historic legislation, funding for, and the reassembly of public lands from private parcels in our study area as well as land sales from vertically-integrated timber companies have had an outsized influence on meeting the design's connectivity and interior forest block targets. However, the rapid gains in land protections made during the past 40 years by private nonprofits are temporally striking, and other authors have noted that the use of conservation easements has grown exponentially in recent years (Fishburn et al., 2009; Merenlender et al., 2004).

Past global conservation has been strongly biased towards the protection of lands at a distance from urban centers and on steep, high terrain, despite the fact that such locations may be incongruous with demonstrated conservation needs (Hunter and Yonzon, 1993; Joppa and Pfaff, 2009; Scott et al., 2001). In the Northeast, low and mid-elevational sites as well as calcium-rich geologies are recognized as underrepresented in conservation (Open Space Institute, 2017). Although we did not see a statistically significant relationship at the county level between elevation and progress towards meeting design targets, this literature is consistent with our basic findings around mean elevation for currently protected lands at the state level. Vermont's highest elevation occurs at just under 1400 meters above sea level (m.a.s.l.) (and its lowest at 29 m.a.s.l.). The mean highest priority conservation design target occurs at 420 m.a.s.l., but the mean protected lands elevation occurs at 493 m.a.s.l., suggesting that Vermont Conservation Design is attempting to rectify historical elevational bias. Surprisingly, the mean protected design target elevation occurs at 527 m.a.s.l.—higher even than the mean for all conserved lands—suggesting that protected design targets may be areas most

attainable through historic conservation efforts.

Conservation easements have been shown to be more effective at protecting middle and lower elevation lands, as well as certain types of ecosystems not widely encompassed by past protections (Gallo et al., 2009; Graves et al., 2019; Scott et al., 2001). To this effect, our findings are consistent with other work that has indicated that nonprofits play an especially important role in the protection of riparian connectivity and surface waters and riparian areas targets within large landscape initiatives (Merenlender et al., 2004). These two elements are also the least protected in the state, although riparian connectivity targets the smallest total amount of land for protection of any landscape design element in Vermont (Fig. 3).

5. Conclusions

Our analyses indicate that the combined efforts of federal, state, and private nonprofits have made significant collective progress towards meeting large landscape conservation design targets via formally protected lands in a region where small parcel sizes and private lands are typical. Examining history demonstrates that public rights to land can successfully be pieced back together even after being transferred to private parties, and our study underscores the fact that doing so can have important eventual benefits for large landscape conservation. Our analysis also reveals that the divestment of vertically-integrated timber companies in the 1990s and 2000s in Vermont has contributed to concrete advancements in realizing large landscape conservation design targets in some parts of the state. While such sales already are—and may be increasingly infrequent in the Northeast (Meyer et al., 2014)—our study can inform the preparedness of conservation actors and their partners in other regions where opportunities for these and other similar types of land sales still exist or may be upcoming. Finally, while we recognize that collaborative efforts are central to conservation in ways that our analysis cannot illustrate, our results point to a huge area of opportunity in regions like ours—that private nonprofits play an important role as the primary interest holders in valuable and underprotected riparian connectivity and surface waters and riparian area design targets, an effort that can continue to be backed by public-private partnerships and other support mechanisms. However, our findings also demonstrate that less accessible biophysical settings that have been historically overrepresented in conservation remain disproportionately embodied in protected design targets in Vermont; a finding which, while unsurprising, suggests that low-elevation lands constitute a continuing gap among protected targets within the conservation design. To this effect, recent regional analyses indicate Vermont and several neighboring states declined in total forestland for the first time in over a century with estimates suggesting that forestlands are now being lost to development at a rate of 600 ha per year (Foster et al., 2017). These trends coincide with significant declines for conservation funding in New England and highlight the challenges to making substantial progress towards the remaining two-thirds of conservation design targets in this region and others. Achievement of such ambitious designs will require a redoubling of efforts through additional land protection strategies, smart development planning, and increased support for conservation initiatives by a variety of actors.

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CRediT authorship contribution statement

Carolyn D. Loeb: Conceptualization, Methodology, Data curation, Visualization, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Anthony W. D'Amato**: Conceptualization, Supervision, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Summary

This shapefile is a hybrid of the March 2017 Edition of the Vermont Center for Geographic Information's Vermont Protected Lands Database (VPLD), the Vermont Land Trust's February 2019 protected lands database, and The Nature Conservancy's Secured Areas (SA 2018+) database. It creates a more complete snapshot of Vermont's protected lands for our purposes than any other publicly available dataset at the time of our study, and also corrects for all improperly overlapping polygons. SA 2018+ and VLT datasets were used as the scaffolding for the hybrid layer, with some VPLD polygons retained if they contained unique contributions. Note that prior to use in the analysis, this layer was modified to exclude waterbodies and to introduce county boundaries. Please see the shapefile's metadata for detailed information about its creation. Supplementary data to this article can be found online at doi: https://scholarworks.uvm.edu/rsmpp/23/.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://scholarworks.uvm.edu/rsmpp/23/.

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