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Research Paper

Improving the utility of existing conservation plans using projected housing development

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HIGHLIGHTS

- We assess vulnerability of and threat to expert-based conservation priorities.
- One third of priority areas are threatened by current housing development.
- Multi-purpose priority areas are more threatened than conservation-only areas.
- Threat and vulnerability metrics can be used to schedule conservation actions.
- This method can add value to existing conservation plans across the US.

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ABSTRACT

Land management agencies frequently develop plans to identify future conservation needs and priorities. Creation and implementation of these plans is often required to maintain funding eligibility. Agency conservation plans are typically expert-based and identify large numbers of priority areas based primarily on biological data. As conservation dollars are limited, the challenge is to implement these plans in a manner that is effective, efficient, and considers future threats. Our goal was to improve the utility of existing, expert- and biologically-based plans using a flexible approach for incorporating spatial data on vulnerability to and threat from housing development. We examined two conservation plans for the state of Wisconsin in the United States and related them to current and projected future housing development, a key cause of habitat loss and degradation. Most (54–73%) priority areas were highly vulnerable to future threat, and 18% were already highly threatened by housing development. Existing conservation investments were highly threatened in 8–9% of priority areas, and 25–34% of priority areas were highly vulnerable and highly threatened, meriting immediate conservation attention. Conversely, low threat levels in 20–26% of priority areas may allow time for new, large-scale conservation initiatives to succeed. Our results highlight that vulnerability to and threat from existing and future housing development vary greatly among expert- and biologically-based priority areas. The framework presented here can thus improve the utility of existing plans by helping to target, schedule, and tailor actions to minimize biodiversity loss in highly threatened areas, maximize biodiversity gains, and protect existing conservation investments.

1. Introduction

Conservation plans are important tools for guiding conservation actions at local to global scales (Moilanen, Wilson, & Possingham, 2009), and ideally identify where, when, and how to act so that conservation goals are achieved, resources are used efficiently, and negative impacts to human communities are minimized (Sarkar et al., 2006). Land management agencies are major conservation actors (Theobald et al., 2000), and frequently develop conservation

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plans to guide their operations, including land protection and management. Agency plans are often developed to meet specific legal or funding requirements (e.g., Wildlife Action Plans in the United States, US Fish and Wildlife Service, 2006). However, priority areas identified in agency plans are also often incorporated into funding and approval processes for land protection, land management, and other conservation actions within and outside of agencies (e.g., Endangered Resources Grant Programs, Wisconsin Administrative Code NR 58, 2008). Thus agency plans may ultimately influence targeting of a much broader set of conservation resources.

Two important decisions in developing conservation plans are the data and the approach planners will use to identify spatial priorities. Government agency plans often are based primarily or exclusively on biological data (i.e., biologically-based, Lerner, Cochran, & Michalak, 2006). This is unfortunate, as many other factors influence both where action may be most needed (e.g., threatening processes and vulnerability to those processes, Wilson et al., 2005) and where agencies are most likely to be able to act (e.g., Knight & Cowling, 2007; Knight et al., 2011). Agency plans are also often expert-based (Cowling et al., 2003; Newburn, Reed, Berck, & Merenlender, 2005; Prendergast, Quinn, & Lawton, 1999), meaning that priorities are identified not by a spatial optimization algorithm, but by consulting with natural resource experts to identify, based on their knowledge, expertise, and familiarity with the available data, the most important locations for conservation action (e.g., Pohlman, Bartelt, Hanson, Scott, & Thompson, 2006). For example, spatial priority areas in most Wildlife Action Plans (created by each state and territory in the United States in 2005) are expert-based (Lerner et al., 2006).

A common characteristic of plans that are biologically-based (and also often expert-based) is that they identify large numbers or sizes of priority areas, covering much of the landscape (Cowling et al., 2003; Lerner et al., 2006). Such plans may be ineffective in helping conservation actors to achieve conservation goals in any one area (Bottrill, Mills, Pressey, Game, & Groves, 2012), and unlikely to identify high-urgency locations where high biodiversity value and high threat intersect (Margules & Pressey, 2000; Pressey, 1994; Pressey & Taffs, 2001).

One approach to address plans which identify many priorities covering large portions of the study region is to incorporate additional (non-biological) data into future plans. However, writing better future plans does not address the situation in which agencies currently find themselves: staff, partners, stakeholders and the public who helped develop existing plans, often over multiple years, have an expectation that current plans will be used. In addition, agencies may be legally required to implement current plans, often valid for up to 10 years, to maintain funding eligibility (e.g., Wildlife Action Plans in the United States, US Fish and Wildlife Service, 2006). What is needed is an alternative, easily-applied approach to increase the effectiveness of existing plans in guiding future conservation actions.

Here we propose using existing biologically- and expert-based plans together with data on vulnerability to and threat from projected future housing development to target, schedule, and tailor future conservation actions. Housing development is a major threat to wildlife and wildlife habitat in the United States (Wilcove, Rothstein, Dubow, Phillips, & Losos, 1998), but is rarely considered in conservation plans (Lerner et al., 2006; Newburn et al., 2005). We define a given area as vulnerable to housing development when there is a lack of protected areas, and as threatened by housing development when either current or projected future housing density is high, or when rapid housing growth is likely. Both vulnerability to and threat from housing development vary greatly in space (Radeloff et al., 2010). Housing development pressure is also usually correlated with land costs (Capozza & Helsley, 1989). Explicit consideration of the location and intensity of threats and land costs in conservation plans can dramatically increase conservation effectiveness and decrease conservation costs (Ando, Camm, Polasky, & Solow, 1998; Naidoo et al., 2006; Newburn et al., 2005). Here we quantify the vulnerability of and threat to individual conservation priority areas from housing development, and use that information to identify where action is most needed (i.e., targeting), when that action needs to occur (i.e., scheduling), and what kind of action may be most suitable (i.e., tailoring).

When applying vulnerability and threat data to existing, expert-based plans, it is important to first understand to what extent these data may have been considered indirectly in plan development. Although expert-based plans are typically also biologically-based, experts creating the plans are often aware of threats facing biodiversity in their region (Cowling et al., 2003; Lerner et al., 2006). They may not agree, however, on the severity, location, extent, or impact of threats (Underwood, Francis, & Gerber, 2011), as expert knowledge can be biased toward places and taxa that the experts know best (Cowling et al., 2003; Maddock & Samways, 2000). Experts may also disagree on the extent to which priority areas in the plan should attempt to minimize biodiversity loss or maximize biodiversity gain (Maguire & Albright, 2005), which may be problematic when plan goals and criteria for identifying priority areas are not specific and clear. A further complicating factor is that expert-based plans are rarely published in the peer-reviewed literature, and thus are rarely evaluated (e.g., Knight et al., 2008). As a result, the conservation value of expert-based plans is poorly understood compared to plans developed using spatial optimization algorithms, and is often discounted.

Our goal was to improve the utility of existing plans as strategic tools for targeting, scheduling, and tailoring conservation actions by incorporating spatial data on vulnerability to and threat from housing development. We had two objectives. First, we sought to quantify, map, and compare vulnerability and threat characteristics of priority areas in existing expert- and biologically-based plans. We examined two conservation plans for the state of Wisconsin in the United States as our case studies. One of the plans, Wisconsin's Wildlife Action Plan, had conservation as its sole goal (WDNR, 2008). The second, Wisconsin's Land Legacy Plan, had dual recreation and conservation goals (Pohlman et al., 2006). Our second objective was to demonstrate the utility of vulnerability and threat metrics for targeting, scheduling, and tailoring conservation actions within existing plans. We used nationwide, publicly available data on vulnerability to and threat from housing development to facilitate application of this approach to other locations. The timing of our study is opportune for Wildlife Action Plans in particular, as all plans must be revised by 2015. We hope that the information presented here, applied in other states, can provide tools for shaping the next round of Wildlife Action Plans to be strategic and effective instruments in targeting conservation investments across the United States.

2. Methods

2.1. Study area

Our study area was the state of Wisconsin, an area of ~145,000 km^2 in the north-central United States. The state is biologically diverse, with over two hundred rare species (WDNR, 2011). Wisconsin is divided into 16 ecological landscapes based on physical and biological characteristics such as topography, soils, and existing and pre-settlement vegetation (WDNR, 2012). A major ecological division occurs between the northern hardwood forests of northern Wisconsin ecological landscapes, and the prairies, savannas, barrens, and oak woodlands that historically dominated southern Wisconsin. Today, much of southern Wisconsin has been

converted to agriculture (Rhemtulla, Mladenoff, & Clayton, 2007). Growing urban centers are concentrated in the south and east (Radeloff, Hammer, & Stewart, 2005). Housing growth in northern Wisconsin is also strong, especially around lakes (Hammer, Stewart, Hawbaker, & Radeloff, 2009; Radeloff, Hammer, Stewart, Fried, et al., 2005). Major threats to biodiversity include habitat loss, invasive species, and pollution (WDNR, 2005), and housing development is the major cause of habitat loss and fragmentation (Radeloff, Hammer, Stewart, Fried, et al., 2005).

2.2. Data

2.2.1. Conservation plans

We examined two conservation plans developed by the Wisconsin Department of Natural Resources together with numerous partner organizations and the public (Pohlman et al., 2006; WDNR, 2008). Wisconsin's Wildlife Action Plan was developed in response to a federal requirement, with the agency's Endangered Resources Program taking the lead. Wisconsin's Land Legacy Plan was developed at the request of a committee appointed by the state governor to assess past conservation efforts and identify future conservation and recreation needs. The agency's land planning program led development of the Land Legacy Plan, although a number of staff were involved in developing both plans. Because both plans included biodiversity conservation as a primary goal, we assumed that all priority areas had high biological value.

The goal of Wisconsin's Wildlife Action Plan was to address the needs of declining wildlife species before they reach the point of possible listing under the federal endangered species law (WDNR, 2005). Criteria for identifying priority areas included locations of high-quality natural communities, rare or declining wildlife species, and large, minimally-fragmented systems along with priority conservation sites in other plans. The final plan identified 198 terrestrial priority areas (33,017 km^2, 22.7% of the state). Priority area boundaries were available from the Wisconsin Department of Natural Resources in GIS format.

The goal of Wisconsin's Land Legacy Plan was to identify the most important places to meet the state's conservation and recreation needs over the next 50 years (Pohlman et al., 2006). Priority areas were identified using biological criteria similar to those for the Wildlife Action Plan, along with additional criteria related to recreation, scenic beauty, access to public lands, and surface and drinking water. The final plan identified 315 priority areas, but mapped only the centroid of each priority area and a size category for its projected final size (small (<500 acres (20.2 km^2)), medium (500–5000 acres (20.2–202.3 km^2)), or large (>50,000 acres (202.3 km^2))). We approximated priority area boundaries as a circle around each centroid with an area of 20.2 km^2, 202.3 km^2, or 404.7 km^2. We excluded from analysis portions of each circle that fell outside of the state boundary. These spatial representations of the priority areas likely encompassed the envisioned project area in nearly all cases, but may have included more area than envisioned for some projects. The resulting Land Legacy Plan priority areas included 58,348 km^2 (40.2% of the state).

2.2.2. Protected lands

We defined protected lands as those publicly owned, permanently eased, or within tribal reservations. We compiled free, publicly available protected lands data in GIS format from two primary sources: (1) permanently protected areas (Conservation Biology Institute, 2012), and (2) permanent conservation easements (National Conservation Easement Database, 2012). We supplemented these sources with publicly-available GIS data on additional lands owned, eased, or leased by the Wisconsin Department of Natural Resources, as well as other lands purchased or permanently eased with state funds for conservation or recreation purposes (WDNR Managed Lands, 2013). A total of 27,723 km^2 in Wisconsin were protected lands, comprising 19.1% of the state. Tribal reservations comprised 9.6% of protected lands in Wisconsin. We note that a small proportion of lands within tribal reservations have been developed, and tribal reservations do not have biodiversity conservation as their sole or even primary land management goal. However, tribal lands generally are not open to development by non-tribal members. Thus we included them as protected lands when assessing vulnerability.

2.2.3. Current and projected future housing density

We used current and projected future housing densities developed by Radeloff et al. (2010) based on 2000 U.S. Decennial Census data. These nationwide data are available in GIS format for free, public download at http://silvis.forest.wisc.edu/maps/housing_main. Housing growth rates from the 1990s were used to project future housing growth in decadal time steps to estimate housing density through 2030. The spatial unit of analysis was the partial block group. Partial block groups are an aggregation of US Census Bureau blocks, and are the smallest geographic unit for which housing development projections are available (Radeloff et al., 2010). The mean size of partial block groups in Wisconsin was 2.03 km^2 (n = 71,702). Housing densities in partial block groups containing protected areas (with the exception of tribal reservations) were modified: protected areas were considered to have no houses, and the housing density in the remainder of the partial block group was increased accordingly (Radeloff et al., 2010).

2.3. Analyses

2.3.1. Vulnerability and threat characteristics of priority areas in conservation plans

We defined vulnerability as the proportion of each priority area identified in each of the two plans that was not publicly owned, permanently eased, or within a tribal reservation. We computed vulnerability by overlaying the protected lands data on the existing plans and calculating the proportion of each priority area not already protected. We calculated three levels of vulnerability: low (>67% of the priority area protected), medium (33–67%), and high (<33%). We chose the thresholds for vulnerability to be simple and straightforward, as we are not aware of general guidelines for what constitutes adequate levels of land protection for biodiversity, and adequate protection levels will depend on many factors, including the specific conservation targets and their sensitivity to human disturbances, including housing (Hansen et al., 2005; Lepczyk et al., 2008; McKinney, 2002; Wood et al., in press).

We assessed threat by considering three distinct layers of the housing data: current housing density (year 2000), projected future housing density (year 2030), and projected housing growth between 2000 and 2030. For each threat metric, we considered both intensity and exposure (Wilson et al., 2005). To do this, we first defined thresholds for housing density and housing growth, to incorporate threat intensity. We used a housing density threshold of 6.2 housing units/km^2 (equivalent to 1 housing unit per 40 acres). This threshold has been used to separate developed areas from wildland areas (Radeloff, Hammer, Stewart, Fried, et al., 2005) and exurban housing from rural lands (Brown, Johnson, Loveland, & Theobald, 2005), and is commonly used in classification of rural land use at the local level (e.g., Town of Woodville, 2012). We used a housing growth threshold of 50% between 2000 and 2030, which we refer to as rapid housing growth.

Next, we quantified each threat for each priority area by overlaying on the existing plans only the partial block groups exceeding the identified thresholds, and calculating the proportion of each

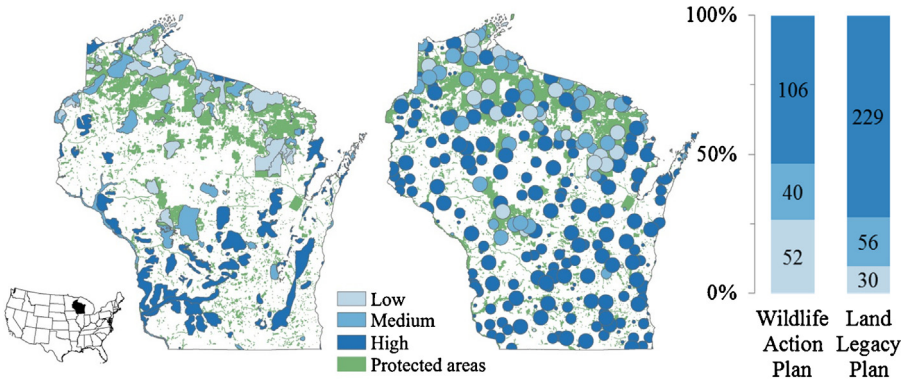

Fig. 1. Vulnerability of priority areas in the Wildlife Action Plan (left) and Land Legacy Plan (right). The location of the state of Wisconsin within the United States is shown in the lower left corner. The ecological division between northern and southern Wisconsin is shown in dark gray. Bar graph indicates percentage (and number) of priority areas in each category.

priority area encompassed by those partial block groups. We defined three levels of each threat metric according to the proportion of the priority area exposed to housing development exceeding the threshold levels for density and growth: low (affecting <33% of the priority area), medium (33–67%), and high (>67%). We chose year 2000 for current housing density, because it represents landscape conditions as the plans were developed. We chose 2030 as the target year for future threat, as it is within the planning window of most agencies and conservation organizations. We chose the thresholds for threat levels that were simple and straightforward, because we are not aware of general guidelines for what level of housing density or growth constitutes a significant threat to biodiversity. Critical levels of threat to priority areas from housing development will depend on many factors, including the specific conservation targets, the sensitivity of those targets to housing development and its associated threats (e.g., human activity, lights, pets, roads, invasive species), and the nature and design of individual housing developments (Hansen et al., 2005; Lepczyk et al., 2008; McKinney, 2002; Theobald, Miller, & Hobbs, 1997; Wood et al., in press).

We compared the Wildlife Action Plan (solely conservation goal) and Land Legacy Plan (conservation and recreation goals) by assessing differences in vulnerability and threats to areas identified in each of the two plans. We also computed the spatially-weighted average current housing density, projected future housing density, and housing growth rate for each priority area in each plan (we weighted values for each metric in each partial block group by the area of the partial block group). We then compared the median value of each metric for all priority areas in an ecological landscape to the value computed for the entire ecological landscape, in each of the 16 ecological landscapes in the state.

2.4. Targeting, scheduling, and tailoring conservation actions

To demonstrate the potential utility of vulnerability and threat metrics for targeting, scheduling, and tailoring conservation actions, we first defined simple, clear, and descriptive categories, using the vulnerability and threat metrics described above, that would be helpful to agencies or organizations as they considered future actions (Table 1). Our primary considerations in developing the categories were: (1) identifying sites with low vulnerability to housing development that are less likely to be targets for ongoing land protection, (2) identifying the time window within which more vulnerable priority areas were likely to come under medium or high threat from housing development (i.e., now, by 2030, or beyond 2030), and (3) considering the investment in land protection that has already occurred within each priority area. We then identified the area of existing protected lands and number and geographic distribution of sites in each category.

Table 1
Description of priority area categories.

	Low vulnerability (>67% of priority area is protected)	Medium vulnerability (33–67% of priority area is protected)	High vulnerability (<33% of priority area is protected)
Low threat[a]	Conservation strongholds	Low threat to existing investments	Promising opportunities for new, large-scale initiatives
Medium threat[b]		High threat to existing investments	Medium-term opportunities for conservation
High threat[c]			Narrow opportunities for conservation

[a] Priority area is not likely to experience medium or high threat from housing development through at least 2030. Specifically, <33% of priority area is exposed to both current and projected future housing development exceeding a density of 6.2 units/km^2 and to rapid housing growth.

[b] Priority area is likely to experience medium or high threat from housing development by 2030. Specifically, <33% of priority area is exposed to current housing development exceeding a density of 6.2 units/km^2, but ≥33% of priority area is exposed to projected future housing development exceeding a density of 6.2 units/km^2 or to rapid housing growth.

[c] Priority area is already under medium or high threat from housing development. Specifically, ≥33% of priority area is exposed to current housing development exceeding a density of 6.2 units/km^2, as well as to projected future housing development exceeding a density of 6.2 units/km^2 and to rapid housing growth.

Finally, we summarized the conservation status, broad conservation considerations, and conservation strategies most suited for priority areas in each category. Considerations and strategies were developed based on the authors' collective five decades of experience in natural resources management at the Wisconsin Department of Natural Resources and other agencies, meetings and informal conversations during that time with other land planning, acquisition, and management staff at the Wisconsin Department of Natural Resources, and the literature.

3. Results

3.1. Vulnerability and threat characteristics of priority areas in conservation plans

A majority (54–73%) of priority areas in both plans were highly vulnerable to future housing development, with low vulnerability

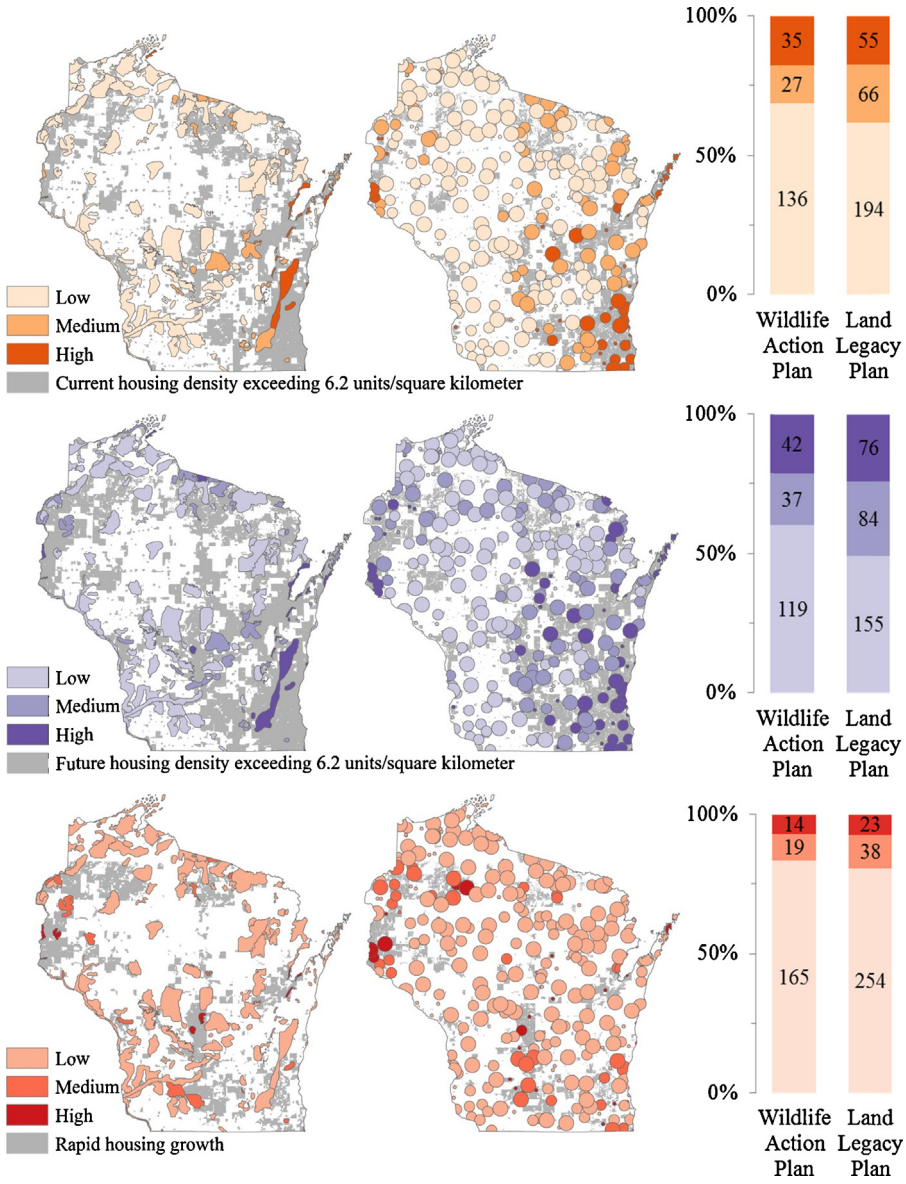

Fig. 2. Threat to priority areas in the Wildlife Action Plan (left) and Land Legacy Plan (right) from current (top) and projected future (middle) housing densities exceeding 6.2 units/km^2 and rapid housing growth (bottom). The ecological division between northern and southern Wisconsin is shown in dark gray. Bar graphs illustrate percentage (and number) of priority areas in each category.

sites in both plans located primarily in northern Wisconsin (Fig. 1). Less than a quarter of priority areas were highly threatened by current or projected future housing density (17–18% and 21–24%, respectively, Fig. 2). Most highly threatened priority areas occurred in more urbanized eastern Wisconsin or in northwestern Wisconsin, within commuting distance of Minneapolis, Minnesota (Fig. 2). Few priority areas were highly threatened by rapid housing growth (7%), and they were scattered throughout the state, including near Minneapolis, Minnesota and urban centers in Wisconsin (e.g., Milwaukee, Madison, Green Bay, Fig. 2).

In our comparison of the conservation-focused Wildlife Action Plan and the dual recreation- and conservation-focused Land Legacy Plan, vulnerability was substantially lower for the Wildlife Action Plan (26% of priority areas had low vulnerability compared to 10% for the Land Legacy Plan, Fig. 1) because more lands were protected (on average 38.2% of Wildlife Action Plan priority areas were already protected, compared to 23.8% of Land Legacy Plan priority areas). Threat was also lower for the Wildlife Action Plan: more priority areas in the Wildlife Action Plan faced low threat from both current and projected future housing density compared to the Land Legacy Plan, although the percentage of priority areas under high threat from current and future housing density was similar for both plans (Fig. 2). The percentage of priority areas under medium or high threat from rapid housing growth was similar for both plans (Fig. 2).

A similar and consistent pattern emerged when comparing spatially-weighted housing densities and growth rates for priority areas in each plan and the broader landscape: Wildlife Action Plan values were consistently lower than Land Legacy Plan values, and both were lower than values for the broader landscape. Median current housing densities within priority areas in the Wildlife Action Plan, Land Legacy Plan, and broader landscape were 4.7, 8.0, and 8.8 housing units/km^2, respectively. Median projected future housing densities in 2030 in priority areas in the Wildlife Action Plan, Land Legacy Plan, and broader landscape were 6.3, 10.6, and 11.9 housing units/km^2, respectively. Finally, housing growth rates for priority areas in the Wildlife Action Plan, Land Legacy Plan, and broader landscape were 19.3%, 24.8%, and 27.3%, respectively.

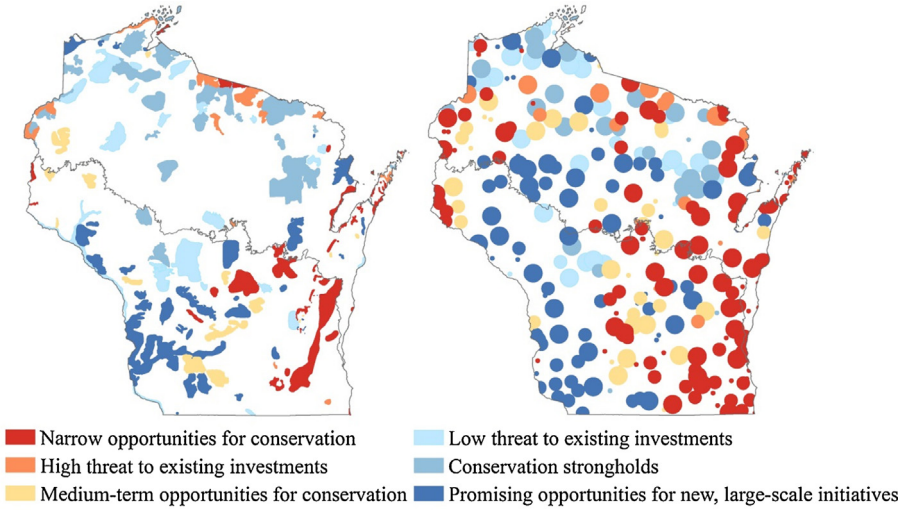

Fig. 3. Categories of priority areas in the Wildlife Action Plan (left) and Land Legacy Plan (right). The ecological division between northern and southern Wisconsin is shown in dark gray. See Table 1 for category definitions.

3.2. Targeting, scheduling, and tailoring conservation actions

Conservation strongholds occurred primarily in northern Wisconsin in both plans (Fig. 3), included 26% of Wildlife Action Plan priority areas and 10% of Land Legacy Plan priority areas, and contained 22–26% of total protected lands in the state (Table 2). The critical consideration for *conservation strongholds* is whether conservation goals have been achieved given the high level of existing protection (Table 3). Because of their low vulnerability to housing development due to much of the priority area being already protected, these sites are unlikely to be targets for significant future land protection (Table 3).

Conversely, a substantial number of priority areas in each plan (25% and 34% for the Wildlife Action Plan and the Land Legacy Plan, respectively) represented *narrow opportunities for conservation*, i.e., they were both highly vulnerable to housing development and already threatened by current housing density (Table 2). Many sites in this category were located in the more developed eastern half of Wisconsin (Fig. 3). In these sites, conservation actors need to decide soon whether to pursue additional land protection. If so, action is needed now. Budgets, landowner support, and the presence of other organizations working to achieve similar goals will help determine whether conservation goals are still attainable and additional investments warranted (Table 3). Where original conservation goals are no longer attainable, alternative goals for or divestment of existing properties should be considered (Table 3).

An additional 20% of sites fall into the category of needing action before 2030, and should be considered for a second wave of action. Priority areas representing *high threat to existing investments* (8–9% of priority areas) were concentrated in northern Wisconsin, while those representing *medium-term opportunities for conservation* (9–13% of priority areas) occurred primarily in central and western Wisconsin (Fig. 3). If conservation goals have not been met in priority areas categorized as *high threat to existing investments*, concerted conservation efforts are necessary soon lest habitat loss and fragmentation from housing development in the surrounding landscape lead to irreversible loss of function for existing protected areas (Table 3). Similarly, if major conservation action is needed to reach goals in priority areas categorized as *medium-term opportunities for conservation*, it should be initiated soon before rising land prices and increasing housing development make conservation action much more difficult (Table 3).

Finally, 30–46% of sites will continue to experience only low threat from housing development through 2030, and as a result have a longer window for conservation action. About a quarter (20–26%) of priority areas were *promising opportunities for new, large-scale initiatives*, many of which were clustered in southwestern Wisconsin (Fig. 3). Fewer (10–12%) priority areas were characterized as *low threat to existing investments*. In priority areas under low threat from housing development, the key consideration is whether land protection is needed to reach conservation goals (Table 3). It may be possible to achieve many conservation objectives in working landscapes using strategies that maintain lands in private ownership (Table 3).

4. Discussions

We examined the vulnerability and threat characteristics of priority areas identified in two existing biologically- and expert-based conservation plans using current and projected future housing density and growth. We found that more than half of priority areas were highly vulnerable to housing development because they lacked protected areas, and over 30% were already threatened by housing development. Priority areas in the plan that focused solely on conservation were less vulnerable to and less threatened by housing development than priority areas in the dual conservation- and recreation-focused plan. Using a combination of vulnerability and threat metrics, we were able to pinpoint: (1) highly vulnerable and highly threatened priority areas meriting immediate conservation consideration, (2) priority areas where action is needed soon before conservation costs increase and opportunities decrease, and (3) low-threat priority areas where land protection action may not be needed or where there is a longer timeframe for conservation action to occur.

4.1. Vulnerability characteristics of priority areas in conservation plans

The average proportion of priority areas already protected in Wisconsin's conservation-focused Wildlife Action Plan (38%) was similar to other expert-based prioritizations (Cowling et al., 2003), identical to the proportion of global hotspots already protected (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000), and higher than in the dual conservation- and recreation-focused Land Legacy plan (24%). The inclusion of numerous priority areas with extensive protected areas (low vulnerability) may reflect the agency's commitment to consolidate and complete individual existing agency projects (e.g., state parks) within these priority

Table 2
Percentage of priority areas (and total area of protected lands) in each category for the Wildlife Action Plan (A, $n = 198$ priority areas) and Land Legacy Plan (B, $n = 315$ priority areas). See Table 1 for category definitions.

	Low vulnerability	Medium vulnerability	High vulnerability
(A) Wildlife Action Plan			
Low threat	Conservation strongholds: 26% (7439.6 km^2)	Low threat to existing investments: 12% (3262.2 km^2)	Promising opportunities for new, large-scale initiatives: 20% (875.4 km^2)
Medium threat		High threat to existing investments: 9% (819.2 km^2)	Medium-term opportunities for conservation: 9% (353.3 km^2)
High threat			Narrow opportunities for conservation: 25% (705.2 km^2)
(B) Land Legacy Plan			
Low threat	Conservation strongholds: 10% (6349.1 km^2)	Low threat to existing investments: 10% (5226.7 km^2)	Promising opportunities for new, large-scale initiatives: 26% (1778.8 km^2)
Medium threat		High threat to existing investments: 8% (2200.4 km^2)	Medium-term opportunities for conservation: 13% (866.1 km^2)
High threat			Narrow opportunities for conservation: 34% (2143.4 km^2)

areas (Acquisition of Recreational Land, Wisconsin Administrative Code § NR 1.40(2)(a), 1985).

Geographic clustering of priority areas with low and high vulnerability in the north and south, respectively, reflected past land protection efforts in the state. Most (79%) protected areas in Wisconsin are concentrated in the north, resulting in a much larger portion of the northern Wisconsin landscape currently being protected (28.9%) compared to the south (8.4%). Southern Wisconsin was historically dominated by prairies and savannas, but less than 1% of the original area of these plant communities remains (Curtis, 1971). The cluster of priority areas categorized as *promising opportunities for new, large-scale initiatives* in southwestern Wisconsin, the area of the state with the best opportunities for maintaining and restoring prairies and savannas (WDNR, 2005), thus provides an important opportunity to focus future protection efforts on these rare natural communities.

4.2. Threat characteristics of priority areas in conservation plans

Nearly one quarter of priority areas were highly threatened by future housing density exceeding 6.2 units/km^2. Minimizing biodiversity loss, by focusing action on areas of high biodiversity value that are also highly threatened, is generally the most effective approach for targeting and scheduling conservation action (Spring, Cacho, Mac Nally, & Sabbadin, 2007; Visconti, Pressey, Segan, & Wintle, 2010; Wilson, McBride, Bode, & Possingham, 2006). Thus identifying which priority areas in existing conservation plans are highly threatened is key for targeting conservation resources on areas most likely to be lost in the near term. The inclusion of numerous priority areas threatened by housing development and growth, particularly in the dual conservation- and recreation-focused Land Legacy Plan, may also reflect the agency's commitment to acquire recreational land near heavily populated areas (Acquisition of Recreational Land, Wisconsin Administrative Code § NR 1.40(1), 1985).

However, there was also evidence that experts sought to maximize biodiversity gain in developing their conservation plans. Across both plans, a majority of sites faced low threat from current and future housing density and rapid housing growth, suggesting that experts are largely: (1) targeting large, minimally fragmented, functioning ecosystems (a stated priority in both plans), and (2) seeking to maximize biodiversity protection rather than minimize the loss of sites facing high threat. Other expert-based prioritizations have also tended to identify minimally impacted, low threat sites (Chown, Rodrigues, Gremmen, & Gaston, 2001; Cowling et al., 2003; Meynard, Howell, & Quinn, 2009). Strategies that seek to maximize biodiversity gain, i.e., targeting areas with high biodiversity value regardless of threat, may be optimal when conservation action will be delayed, budgets are limited or uncertain, threat levels are similar across the landscape, or differing threat levels have similar impacts on conservation targets (McBride, Wilson, Bode, & Possingham, 2007; Visconti, Pressey, Bode, & Segan, 2010; Wilson, McBride, Bode, & Possingham, 2006). Thus expert-based plans may reflect a combination of multiple strategies: minimizing biodiversity loss, maximizing biodiversity gain, and building on existing conservation investments.

4.3. Targeting, scheduling and tailoring conservation actions

We demonstrated the utility of vulnerability and threat data for targeting, scheduling, and tailoring conservation actions among priority areas in existing biologically- and expert-based conservation plans. Vulnerability and threat metrics have also been used to prioritize biologically important sites for action at a global scale, and to highlight conservation strategies that may be most effective under specific vulnerability and threat conditions (e.g., Brooks et al., 2006; O'Connor, Marvier, & Kareiva, 2003). Agency priorities reflect many considerations in addition to biodiversity conservation, including legal, social, political, and cultural factors that are beyond the scope of this paper. However, the intensity and extent of threat posed by housing development, and the differing vulnerability of conservation priority areas to that threat, suggest clear differences in: (1) the need for continued land protection, (2) the timeframe in which conservation actions are likely to be feasible and effective in maintaining the conservation value of sites, and (3) the types of conservation actions which may be most suitable.

Much of the landscape has been successfully protected in *conservation strongholds*, and the return on investment is likely to be lower (Withey et al., 2012). *Conservation strongholds* where conservation goals have been achieved should not be targeted for further land protection action, but may be high priorities for land management (Table 3).

We suggest that practitioners focus efforts first on the roughly 30% of priority areas with *narrow opportunities for conservation* if their goal is to minimize biodiversity loss from housing development. The potential return on conservation investment in sites that are both highly vulnerable and highly threatened may be quite high (Withey et al., 2012). However, it is important to first assess the feasibility of reaching conservation goals in these highly developed landscapes. In a world of limited budgets, agencies should not allocate scarce resources to areas where conservation goals cannot be met even with protective measures (Bottrill et al., 2008, 2009).

We suggest that practitioners next consider the ~20% of sites categorized as *high threat to existing investments* and

Table 3
Conservation status, considerations and actions for priority area categories. See Table 1 for category definitions.

Conservation strongholds
Status
Significant resources have been invested in land protection, and land protection goals are likely met or nearly met. Development pressure outside protected areas varies, but landscape-level connectivity is likely achieved (With & Crist, 1995).
Considerations
1. Assess whether conservation goals have been achieved in light of significant land acquisition efforts.
a. If so, new acquisitions are likely unwarranted.
b. If not, assess key threats to conservation targets. If habitat loss or fragmentation is not (or no longer) a key threat, additional land protection is likely unwarranted.
c. If unclear, monitoring or research is needed to answer this question before additional conservation actions are taken.
Actions
1. These areas are the lowest priority for additional acquisitions unless exceptional opportunities arise to protect critical target communities or populations.
2. Focus instead on efficient, broad-scale resource management that meets the process and habitat needs of conservation targets.
3. Conservation easements, outreach and technical assistance targeting surrounding landowners can help buffer protected areas and increase the conservation value of matrix lands.

Narrow opportunities for conservation
Status
Land protection efforts are likely far from acquisition goals. The landscape is parcelized and fragmented by housing densities exceeding 6.2 units/km^2, and further threatened by future development. Land prices and recreational potential are high, land management is complex and costly, and the matrix between protected parcels is likely to be developed in the near future.
Considerations
1. Consider the feasibility of achieving conservation goals given ecological requirements of conservation targets (e.g., area- and edge-sensitivity) and the overlap of projected housing growth with critical habitat and buffers surrounding existing protected lands. Conservation targets less sensitive to development and/or are able to persist in smaller, isolated patches may still be viable.
2. Consider alternate or broader (e.g., education, recreation, water quality) goals for sites where attaining conservation goals is no longer feasible.
3. Consider current and future funding availability in light of the estimated cost of protecting adequate habitat for long-term persistence of target populations (McBride et al., 2007).
4. Consider the level of project support from all sectors (agency, partners, stakeholders, landowners, public), given that significant and expensive actions will be required in the near term to achieve conservation goals.
5. Buffering existing protected areas to protect their conservation value is critical given projected future development (Armsworth, Daily, Kareiva, & Sanchirico, 2006; Radeloff et al., 2010; Wood et al., in press).
Actions
1. Simplify land management to reduce cost and complexity if original conservation goals can no longer be met but new goals are identified (Fuller et al., 2010).
2. Consider sale or swap of sites where conservation goals are no longer feasible (Fuller et al., 2010; Strange, Thorsen, & Bladt, 2006).
3. New acquisitions, if pursued, should be adjacent to existing protected areas or large enough to function as stand-alone units.

High threat to existing investments
Status
Significant resources have been invested in land protection, existing land management costs are likely substantial, and the matrix between protected lands is likely to be developed within two decades.
Considerations
1. Assess the extent to which conservation goals have been achieved given the substantial land protection efforts to date.
a. If goals have been met, or if additional land protection is unlikely to abate threats, treat as *conservation strongholds*.
b. If goals have not been met and habitat fragmentation and loss are key threats, assess the spatial pattern of current and projected future housing development within the priority area to identify localized development hotspots, their proximity to existing protected areas, and their overlap with critical habitat for conservation targets.
2. Buffering existing protected areas to protect their conservation value is critical given projected future development (Armsworth et al., 2006; Radeloff et al., 2010; Wood et al., in press).
Actions
1. These areas are high priorities for additional land acquisition if needed to meet conservation goals. Land protection should focus on high-quality habitat (especially in areas projected to be development hotspots) that is adjacent to or has the potential to connect existing protected lands.

Medium-term opportunities for conservation
Status
A substantial amount of conservation 'flexibility' still exists on the landscape, and prices are likely to be moderate. Housing pressure and land prices will increase substantially, and matrix lands between protected areas are reasonably likely to develop, in the next two decades.
Considerations
1. Attaining conservation goals is likely still feasible, but consider the overlap of projected future development with lands where protection is considered necessary to meet conservation goals.
Actions
1. These areas are medium priorities for additional land acquisition. Opportunities to acquire large patches of high-quality habitat (i.e., able to support conservation targets over the long-term as stand-alone properties) should be a priority, along with properties that are: (1) adjacent, near, or well-positioned to connect existing protected lands, and (2) projected 'development hotspots' that would destroy large patches of high-quality habitat or degrade existing protected areas.

Low threat to existing investments
Status
Substantial resources have been invested in land protection, but land protection goals are unlikely to have been reached. Threat from current and future housing development is low in these working landscapes.
Considerations
1. Assess whether conservation goals have been achieved. In either case, consider whether additional land protection is needed to meet conservation goals given the low threat from housing development (Polasky, Nelson, Lonsdorf, Fackler, & Starfield, 2005).
2. Assess the spatial pattern of development within the priority area to determine if localized 'hotspots' exist (or are projected to develop) near protected lands or in areas of high quality habitat for conservation targets.
Actions
1. These areas are low priorities for additional acquisition unless good opportunities arise to build on existing investments, i.e., high quality habitat that is likely to be developed in the short term *and* (1) would expand or connect existing properties, or (2) is of a quality and size warranting protection as a stand-alone property.
2. Work with local units of government to identify issues of common concern (e.g., land-use planning, zoning, and building practices) and support initiatives likely to positively affect conservation goals.
3. Provide technical assistance to landowners surrounding existing holdings to encourage and support land use practices that would increase the conservation value of land while maintaining its economic value.

Table 3 (*Continued*)

Promising opportunities for new, large-scale initiatives
Status
Relatively little land has been protected, ample flexibility exists on the landscape, and land prices and development pressure are low and projected to remain low for at least two decades. Habitat fragmentation is generally not a concern, with the possible exception of area-sensitive species.
Considerations
1. Consider additional and longer term threats before pursuing conservation action to confirm that conservation targets are indeed threatened.
2. Assess the spatial pattern of development within the priority area to determine if localized development 'hotspots' exist (or are projected to develop) near protected lands or in areas of high-quality habitat for conservation targets.
3. Consider whether land protection is needed to meet conservation goals given the low threat from housing development (Polasky et al., 2005).
Actions
1. Pursue opportunities to acquire large habitat patches. Adjacency is not critical, as surrounding areas are not likely to develop in the near future.
2. Work to maintain lands in private ownership while increasing their conservation value through outreach and education, technical assistance to landowners, and landowner incentive programs.
3. Work with local units of government to identify issues of common concern (e.g., land-use planning, zoning, and building practices) and support initiatives likely to positively affect conservation goals.
4. Build project support by surveying landowners to identify common interests and concerns that may be addressed by conservation actions.

medium-term opportunities for conservation. In these sites, high threat from housing development by 2030 will soon diminish conservation opportunities, increase land protection costs, and degrade existing protected areas that are not buffered (Table 3).

Approximately one third of priority areas have a longer window for conservation action because of low threat levels (*low threat to existing investments* and *promising opportunities for new, large-scale initiatives*). Priority areas considered *promising opportunities for new, large-scale initiatives* are often new or proposed projects. These are optimal sites for maximizing biodiversity gain, especially for area-sensitive species and natural communities under-represented in the current protected area network. However, it is important to first assess additional and longer term threats. The protection of sites not under threat has a long history (Pressey, 1994), and is partially responsible for the existing disproportionate representation landcover types in protected areas (Joppa & Pfaff, 2009; Scott et al., 2001).

Two broad conservation considerations also emerged from our analysis. First, expert-based plans, like any systematic conservation planning effort, should be based on specific conservation targets and measurable goals for each (Margules & Pressey, 2000). This is still a common concern: clear, measurable goals were lacking in 72% of state Wildlife Action Plans (Lerner et al., 2006). Often only land acquisition goals are set, assuming that conservation goals will be met (and only met) when the acquisition goal has been reached. The second consideration is when to pursue action in vulnerable priority areas, where little or no land has been protected to date. The potential contribution of conservation action at these sites should be evaluated in terms of likely changes in the landscape given no intervention (Marone, Rhodes, & Gibbons, 2013), statewide representation goals for conservation targets, and complementarity to the existing protected area network. Representation and complementarity are fundamental concepts in conservation planning (Margules & Pressey, 2000; Pressey, Humphries, Margules, Vanewright, & Williams, 1993), and their importance is paramount when considering new conservation initiatives in highly threatened areas where land protection is difficult, costly, and often controversial. However, both are difficult to evaluate in the absence of identified conservation targets and goals.

4.4. Limitations

Our study highlights a number of limitations and future opportunities. First, we examined only one type of threat. Housing development is an important and pervasive threat to wildlife across the United States (e.g., Hamilton et al., 2013; Hansen et al., 2005; Theobald, Miller, & Hobbs, 1997), and elsewhere (Sutherland et al., 2006). Thus we suggest that our work is quite relevant to other countries where housing development is a major driver of habitat loss. Incorporating information on additional threats, including the distribution of invasive species, pollution, disease, and other types of land use change, could further improve conservation effectiveness (Hamilton et al., 2013; Wilson et al., 2007). We suggest that the framework presented here can easily accommodate additional or alternate threat data, tailored to the major conservation threats in the region of interest.

Second, the spatial unit of analysis here (partial block groups) is the finest resolution available on a national scale (Radeloff et al., 2010), but may not capture highly localized threats. For species that are very sensitive to development, such as ground nesting birds (McKinney, 2002), the construction of even a small number of houses may substantially decrease habitat quality over a large area due to noise, lighting, human disturbance, vegetation alteration, and pets (Hansen et al., 2005; Theobald, Miller, & Hobbs, 1997).

Third, we used circular approximations for priority areas in one plan. While this approach introduces error (Visconti et al., 2013), it may be necessary to make use of agency plans, as agencies are often reluctant to delineate exact boundaries showing where future actions are likely.

Fourth, we did not address complementarity or irreplaceability (the number of sites available on the landscape to achieve conservation targets) of priority areas. Such an analysis is more difficult to conduct for expert-based plans, which, by definition, were not produced using algorithms that identify an optimal network of sites meeting specific conservation targets for the study area. Finally, we did not consider the impact of the threat on the conservation targets, which will differ by target species/community and many other factors (Wilson et al., 2005).

5. Conclusions

Conservation dollars are always limited, as are the time and resources that agencies and organizations can allocate to land protection, habitat management, and other conservation actions. For conservation plans to be effective, they must be able to target actions toward areas most in need of protection, and identify the timeframe in which action is needed and the type of actions like to be most effective, while at the same time minimizing conflicts with human activities. Agencies and organizations have already developed many plans to identify future conservation needs and priorities, and they are often mandated to operate under these plans. Planning initiatives can be years-long processes, and require substantial staff and funding resources (Bottrill & Pressey, 2012; Groves et al., 2002). The challenge now is to implement these plans in a manner that is both effective and cost efficient. While developing new and better conservation plans is often advocated, we suggest that it is important to consider approaches for adding value to existing plans which are already in use.

We have presented a straight-forward and easy-to-replicate method for improving the utility of existing biologically- and often expert-based conservation plans by incorporating publicly available, nationwide data on vulnerability to and threat from housing development. We were able to identify which priority areas in existing plans were most vulnerable to threat, which are currently exposed to the highest level of threat, and which are likely to be threatened in the near future. Taken together, these metrics allowed us to identify the subset of vulnerable sites where land protection action should be targeted. Within that subset, we identified which sites are in need of immediate action, and where delayed action may still achieve conservation goals. Finally, we identified conservation considerations and strategies most suited to sites with specific vulnerability and threat characteristics. This approach can help conservation practitioners use existing plans to better identify high urgency sites where quick action is needed to minimize biodiversity loss, sites where existing investments on the landscape are highly threatened, and sites where biodiversity gain can be maximized through new, large-scale initiatives targeting species or communities not adequately represented in the current protected area network. It can also help agencies practice informed opportunism (Noss, Carroll, Vance-Borland, & Wuerthner, 2002) by better understanding the conservation trade-offs inherent in acting on land protection opportunities as they arise. Finally, our approach can be used to refine the boundaries, goals, and conservation strategies of existing plans as they are revised, and may represent a key opportunity for assuring that the next round of Wildlife Action Plans, to be produced by 2015, will be strategic and effective instruments in targeting future conservation investments across the United States.

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