Improving conservation effectiveness and addressing the planning-implementation gap:

a perspective from Wisconsin

By

Sarah Kathleen Carter

A dissertation completed in partial fulfillment of

the requirements for the degree of

Doctor of Philosophy

(Forestry)

at the

UNIVERSITY OF WISCONSIN – MADISON

2014

Date of final oral examination: November 3, 2014

This dissertation is approved by the following committee:

Volker Radeloff, Professor, Department of Forest and Wildlife Ecology
Anna Pidgeon, Associate Professor, Department of Forest and Wildlife Ecology
Murray Clayton, Professor, Departments of Statistics and Plant Pathology
David Mladenoff, Professor, Department of Forest and Wildlife Ecology
Adena Rissman, Assistant Professor, Department of Forest and Wildlife Ecology

Abstract

Conservation planning emerged several decades ago to identify where conservation action can most effectively and efficiently protect biodiversity. The field has since undergone many technological advances. Important questions remain, however, including whether conservation plans influence conservation actions, whether the properties protected were actually threatened, and whether the factors considered in developing plans are the key information needed to enable implementation to occur. I addressed these questions using Wisconsin as a study area and land protection as an evaluation metric.

I first asked whether statewide conservation plans and local conservation projects were associated with changes in the quantity, location, and landcover type of subsequently protected lands. I found a weak relationship between statewide plans and land protection actions: two of four plans were associated with increased land protection. However, 58% of lands protected within 20 years of plan completion were outside plan boundaries. Conversely, the approval of local-scale land protection projects was positively associated with subsequent land protection actions.

I then improved the utility of existing, biologically-based conservation plans by incorporating data on vulnerability to and threat from projected housing development. I found that 25-34% of priority areas in plans merit immediate conservation attention, as they are both highly vulnerable and highly threatened. Conversely, 20-26% of priority areas are vulnerable yet face low threat, likely allowing time for new, large-scale conservation initiatives to succeed.

Finally, I evaluated implementation of conservation plans over time, and identified environmental, institutional, and socio-economic factors associated with implementation success.

I found that 45% of lands inside plans are currently protected, compared to 5% of lands outside plans. Key factors explaining successful implementation were 1) prior successful land protection, 2) having agency authorization for land protection in place before plan completion, and 3) the presence of open water. The latter two factors are priorities in the agency's land protection policy.

My findings suggest that broad-scale conservation plans are most likely to influence land protection actions when they are linked to specific, local projects, when threat and vulnerability characteristics are used to prioritize implementation actions, and when plans consider institutional and policy factors that may facilitate action.

Acknowledgements

Over the last four years, I have been thankful so many times to have been lucky enough to come back to graduate school and work with so many wonderful people in such a great program. Let me first thank my advisors, Volker and Anna. You accepted me so warmly and have been a pleasure to work with ever since. Volker, you have provided inspiration, encouragement, great ideas, and valuable guidance so many times. Anna, I am so grateful for your help, your insightful questions, your amazing edits on presentations, and for the example you set for other mothers pursuing a career in science. It has been fun and rewarding working with both of you, and I hope that we will continue to work together for many more years.

A sincere thank you as well to my committee, Adena Rissman, David Mladenoff, and Murray Clayton. You have all helped to stimulate my work with great conversations and insightful questions. You have been so generous in sharing your knowledge, time, and experience, and I am very grateful that you all agreed to help me along this journey.

Thank you as well to my friends at the Wisconsin Department of Natural Resources who assured me that it wasn't an entirely crazy idea to quit my job and return to school after more than a decade in the agency. I've learned so much from all of you. My dissertation would not be what it is without your input and ideas. Thanks especially to John Pohlman for really great conversations over coffee on many a morning. You were my sounding board, to make sure that what I thought was true about conservation in the agency was in fact true. You had more great research ideas than I had years in graduate school, but I hope we can keep in touch and maybe even pursue some of those ideas in the years to come. Another special thank you to Tara Bergeson, with whom I've had a series of lovely lunch dates full of great science and great friendship. You never

fail to provide a new and cool angle on the questions that I've been thinking about, and I'm grateful for every one of them.

Thank you as well to the other great colleagues and friends that I've met along the way. Tracy Hmielowski – it's been a pleasure working and talking with you about fire and science and life. Steph Januchowski-Hartley – you've been a great mentor, so familiar with the conservation planning world, and so generous in sharing your time and knowledge. Thank you as well to the IGERT group – Emily Atkinson, Jacob Usinowiz, Sam Munoz, Alex Latzka, Andrew L'Roe, Christina Locke, and Drew Hasley, to name just a few. It's been fun to think about novel ecosystems and conservation in general with such a great group of people.

SILVIS. Where to start. It's hard to express how much the people in our lab have made my graduate school experience great. Chris Hamilton – you are an amazing person, and I'm really lucky to have been here at the same time as you. I so appreciate your wisdom, example, encouragement, support, and just plain awesome knowledge of the real world of conservation. Two other amazing people welcomed me into my first office at SILVIS – James Burnham and Matthias Baumann. I'm sure I was a most unlikely fourth in our office, but you welcomed me with open arms, laughter, and a caliber of scientific thinking that I continue to be in awe of. Shelley Schmidt – without our lunchtime chats, I'm not sure how I would have maintained my sanity. Thank you so much for your friendship and wise perspective on so many things. I will miss you! Patricia Alexandre, Brooke Bateman-Plumb, Jess Gorzo, and Anna Estes – it was such a pleasure sharing the stock with you. Thanks for being just all around fabulous office mates and friends! Dave Helmers – your level-headedness, always pleasant nature, and competence are much appreciated by all of us. Nick Keuler – your statistical knowledge and patience are amazing. Alexia Sabor – we thought you were crazy coming back to school, but then I did it too,

so maybe we weren't completely crazy. Sebastian Martinuzzi – you set the bar for how to review a paper. I will miss you popping in to say hello and provide some nugget of wisdom on conservation and life. Eric Wood – your enthusiasm for science and life is inspiring, and your advice on finding a post doc invaluable. And to so many others – your company, conversations, caring, and friendship have made graduate school even more fun and welcoming than I ever anticipated. Thank you!

A special thanks to other friends, near and far. Ellen Roberts – we've been best friends since 4th grade, and, pretty miraculously, both went back to school at the same time. Your belief that we could in fact do this helped keep me going. Thanks for being the most wonderful person that you are, and for, of course, our amazing Greek adventure to celebrate our milestone birthdays and (hopefully!) eventual graduation. Michelle McGuire – your friendship, understanding, and encouragement has boosted my spirits so many times. And many thanks to Susie & Jim Madden, Greg & Mikel Esser-Domnitz, Dan & Robin Ryan, Andrea & Paul Dearlove, and so many others who helped me through graduate school by being wonderful friends and, on occasion, providing a place to play and fabulous children for my kids to play with, so I could do some work.

Thank you to my sister, Lizabeth, for many long distance conversations about the craziness that life and work and school can be, and about how we need to enjoy every precious minute that we are here despite all of that craziness. And to my brothers, Jeff and Dan, for keeping me grounded amidst all of this scientific pontificating. And to my Mom and Dad, Beth and Gib - you are both inspiration and proof that one can indeed return to school and make it through. Without your support in so many ways, this adventure would not have happened. And thank you as well to my parents-in-law, Marilyn and David, for helping in multiple ways, including the day each week when the kids got to 'spend the afternoon with Nan' so I could work a little bit longer.

Last, and most of all, I thank my husband and children. When I came back to school four years ago, we had an 8 month old, a kindergartener, and a second grader. My daughter Nessa was starting her first year of school at age 4, while I was starting my 22nd at an age much older than that. We were both nervous, and we've both learned since that school is totally do-able if you work hard, and very often a lot of fun. Hazel has literally grown up while I've been a graduate student, and is now starting her own first year of school. Isaac is now a middle schooler. He asks me often what I've been working on during the day, and told me the other night that he knows that I 'love school'. It's true, and I hope that feeling has rubbed off on them. Unfortunately, along the way, I've missed many family dinners, soccer games, and other events. I've also bribed the kids with Babcock ice cream more often than I'd like to admit when I had to come back to school for a meeting or to finish a project. I'm at peace with the bribes (who doesn't like a good ice cream cone), but sad to have missed everything that I did. I tried really hard to be there for the important things, and hope that I was. Thank you, Isaac, Nessa, and Hazel for being such understanding, supportive, fun-loving, and wonderful kids!

And finally, a huge thank you to my husband, Andy. It's hard to even express how grateful I am for you. This was a crazy idea from the beginning, and we have reiterated how crazy it is many times since. Yet through it all, you have been so helpful, supportive, encouraging and wonderful. Not only have you picked up the slack at home on many an evening, but you've also been my sounding board for science, policy, planning, management, and statistical questions; and my reminder to keep my dissertation grounded in reality. Thank you so much for being the amazing person, husband, and father that you are, and for everything that you've done to help me finish this adventure!

I am also very grateful for the funding for this dissertation provided by a McIntire-Stennis Fellowship, a PEO Scholar Award, and the NSF-IGERT award DGE-1144752: Novel ecosystems, rapid change, and no-analog conditions: the future of biodiversity conservation in human-dominated landscapes.

Table of Contents

List of Figures

List of Tables

List of Appendices

Executive Summary

Introduction

Ecosystems across the globe have been profoundly affected by people, with humans appropriating nearly half of the earth's primary productivity (Vitousek et al. 1997) and influencing 83% of its lands (Sanderson et al. 2002). Humans influence landscapes both directly (e.g., land use change, hunting) and indirectly (e.g., introduction of pets, invasive species). The consequences for wildlife can be dire, with habitat loss and degradation being the single greatest cause of species endangerment in the US (Wilcove et al. 1998) and the world (Schipper et al. 2008). The challenge for conservation biologists and practitioners is to protect species, their habitats, and the processes that support them while minimizing negative impacts to human societies (Sarkar et al. 2006). Addressing this challenge calls for conservation actions that are both effective and efficient, and requires that conservation biologists and practitioners know which actions are most needed, when they are needed, and where they need to occur (Wilson et al. 2007). The field of systematic conservation planning emerged to address this need (Margules & Pressey 2000).

Systematic conservation planning, and more specifically spatial conservation prioritization (Moilanen et al. 2009), seeks to conserve biodiversity by identifying networks of protected areas based on core concepts of representation, complementarity and persistence. I use the term conservation plan in this sense throughout this dissertation, i.e., plans that identify, based on the concepts of representation, complementarity, and persistence, the most effective and efficient locations for biodiversity conservation over the long term (Margules & Pressey 2000). Conservation plans are developed through a number of steps, beginning with identification of key stakeholders and needed data, encompassing identification of proposed conservation priority

areas, and extending through implementation and subsequent monitoring and reassessment of conservation plans (Margules & Sarkar 2007). The conservation planning process is now well developed (Moilanen et al. 2009), but the evaluation of conservation plans in guiding conservation actions is just beginning (Bottrill et al. 2012; Bottrill & Pressey 2012). This is where I focused my dissertation.

Qualitative surveys of people who developed or were responsible for implementing conservation plans suggest that few published plans are ever intended for implementation, but rather focus on refining existing methodologies or developing new ones (Knight et al. 2008). Of the plans that are intended for implementation, implemented actions are rarely (13%) considered highly effective (Knight et al. 2008). In other words, there is a worrisome disconnect between the development of plans and their actual implementation. This disconnect has been referred to as the planning-implementation gap or implementation crisis (Knight et al. 2008), and is a manifestation of the broader research-management gap that is present across many fields (e.g., fisheries biology (Fausch et al. 2002), business management (Starkey & Madan 2001).

Biodiversity conservation can be achieved through many actions, including species and habitat management, policy and legislation, education, training/capacity building, and research (Kapos et al. 2009). Land protection continues to be the backbone of many conservation strategies (Bengston et al. 2004), and is one of the primary outcomes expected by staff and stakeholders developing conservation plans (Bottrill et al. 2012). Given the extensive resources invested by agencies and organizations in conservation planning (Groves et al. 2002) and land protection (Lerner et al. 2007), the question arises: are conservation plans influencing land protection actions? This was the subject of the first chapter of my dissertation. Specifically, I asked whether completion of conservation plans was associated with changes in the amount, location, and land

cover composition of subsequently protected lands. Such information can help address the planning-implementation gap by allowing practitioners to evaluate the strengths and weaknesses of past planning efforts, enabling future initiatives to both build on past successes and focus attention on addressing identified weaknesses.

While it is important to lay the groundwork for developing better conservation plans in the future, it is equally important to develop ways to better use the plans that are already in place. Natural resource management agencies and non-governmental conservation organizations frequently develop conservation plans both voluntarily and to comply with laws and funding requirements. Once approved, it is expected, and sometimes required by law, that these plans will be used to guide the organizations' actions. Such plans are generally based on biological criteria (e.g., protecting important habitat for rare species (Branton & Richardson 2011; Lerner et al. 2006)). A common and problematic characteristic of biologically-based plans is that they identify many, many 'priorities' for action (Lerner et al. 2006). Spreading limited resources among too many different projects or locations is ineffective in reaching conservation goals (Bottrill et al. 2012). Thus a methodology is needed that allows agencies to 'prioritize the priorities'. That is, we need to understand where action is needed immediately if we are to meet conservation goals for the site, and where action could be delayed without compromising long term conservation prospects. Assessing the threats to and vulnerability of individual priority areas can provide such information (Wilson et al. 2005). In the second chapter of my dissertation, I undertook such an assessment by developing a methodology to increase the effectiveness of existing, biologically-based plans using threat and vulnerability characteristics of individual priority areas in plans. The application of such an approach retroactively to existing plans can help agencies and organizations to pinpoint, from among the many identified priority

areas in plans, where to best allocate resources to minimize biodiversity loss, protect existing conservation investments, and maximize long-term conservation gains (Spring et al. 2007).

In the third chapter of my dissertation, I sought to better understand the institutional, environmental, and socio-economic factors that explain the success (or failure) of efforts to implement conservation plans. Local, regional, and national policies, politics, and economic conditions shape opportunities for conservation action (Radeloff et al. 2013). In addition, socio-economic factors such as income and education may influence attitudes of individuals toward conservation actions (Ahnstrom et al. 2009; Kideghesho et al. 2007). Land ownership patterns and attitudes may limit opportunities to protect land (Knight et al. 2011b). Public attitudes toward local, state, and federal government may influence the willingness of agencies and organizations to work in specific locations (J. Pohlman, *pers. comm*.). Each of these factors varies over time and across space (Stephanson & Mascia 2014). While numerous authors have alluded to the importance of social, economic, and institutional factors in shaping implementation opportunities (e.g., Cowling & Wilhelm-Rechmann 2007; Knight et al. 2011a), I am not aware of any previous quantitative assessments that identify specific factors explaining where implementation efforts have been successful and where they have not. Identifying such factors can help conservation planners and practitioners both understand the circumstances under which implementation is most likely to succeed, and write future plans that are more feasible to implement because they incorporate relevant socio-economic and institutional considerations.

Throughout my dissertation, I take the view that planning is inherently a rational process, which has and can give reasons justifying a course of action (Alexander 2000). A number of planning paradigms exist, including classic rational planning, communicative practice, coordinative planning, and planning as frame setting. These and other paradigms can be complementary, with

the potential for different paradigms to operate at different points within the same planning process (Alexander 1998). Key factors in describing the paradigms and the periods within a process at which they hold true include the actors involved, the focus and ultimate aim of the process, and the desired end product (Alexander 2000).

In this dissertation, I offer conceptual models describing the process of implementing conservation plans through land protection based on the knowledge and experience that I and other collaborators have specifically with conservation planning and land protection in Wisconsin, focused on activities taken specifically by the Wisconsin Department of Natural Resources to protect land within the state for the purpose of biodiversity conservation (please see Figs. 1 and 10, and associated methods in Chapters 1 and 3). Importantly, however, I do not seek explicitly to test these conceptual models. Rather I use the models as a framework for identifying quantitative metrics which are logically related to the planning process, actors, and anticipated outcomes. I then test to determine whether there is a statistical association between the metrics and the end product (the location and timing of land protection transactions). As such, I do not assume nor test a theory of causality. The lack of a control (i.e., a circumstance in which we could observe would have happened in Wisconsin at the same time in the same place in the absence of a conservation plan) makes such a test difficult.

Dissertation goal and objectives

My overall goal was to evaluate the effectiveness of conservation plans in guiding conservation actions. I had three objectives:

1. Evaluate the influence of conservation plans on subsequent conservation actions,
2. Develop an approach for improving the effectiveness of existing plans, and

3. Identify which environmental, socio-economic, and institutional factors best explain implementation success.

To explore each objective, I used Wisconsin as a study area and focused on land protection as the conservation action of interest. Wisconsin has a long history of conservation planning and action, and the state management agency, the Wisconsin Department of Natural Resources, has actively protected land for conservation purposes for more than a century. The availability of historic conservation plans in combination with land protection records dating back more than a century provided an opportunity for comprehensive, quantitative assessments of the relationship between plans and land protection actions over time. While land protection continues to be an important conservation strategy, the lessons learned from my analysis also provide a window into the potential impacts of plans more broadly, and serve as a call to improve monitoring and documentation of other types of conservation outcomes (e.g., changes in conservation awareness and funding).

Chapter summaries

In Chapter 1, I evaluated the influence of conservation plans on subsequent conservation actions. While agencies commonly develop conservation plans, agency actions are often driven by broad missions. Biodiversity conservation goals exist alongside commitments to provide recreational opportunities to the public and stimulate the local economy. Clearly these goals are related and overlap in multiple ways. The meaning of some terms has also changed over time, such that conservation was viewed as a component of recreation in the early 1900s in Wisconsin, while today the terms tend instead to be used separately while acknowledging that they are related (see Table 1 and Appendix B). My question was whether the specific priorities in conservation plans are ultimately reflected in the lands that agencies protect. Specifically, I asked whether

completion of statewide conservation plans and approval of local conservation projects (e.g., a proposed state wildlife area) were associated with changes in the amount, location, and landcover composition of subsequently protected lands. I found a weak relationship between statewide plans and land protection actions. Completion of two of four plans was associated with an increase in land protection statewide or within plan boundaries. However, 58% of lands protected within 20 years of plan completion were outside plan boundaries. Further, the proportion of statewide land protection activity focused inside plan boundaries was lower or not different after plan completion for three of four plans. Conversely, there was a strong positive association between approval of local land protection projects and subsequent land protection actions. My results suggest that broad-scale conservation plans are most likely to influence land protection actions when they are linked to specific, local land protection projects. Ideally this linkage occurs through an agency-authored implementation strategy, in which the agency specifically commits to, and authorizes staff and resources for, implementing a small subset of priorities in the near term from within the larger conservation plan. This work is now published in Biological Conservation (Carter et al. 2014a).

In Chapter 2, I improved the effectiveness of existing, biologically-based conservation plans using data on threats to and vulnerability of individual priority areas within statewide conservation plans. While the biologists who develop plans are certainly aware of threats on the landscape (Cowling et al. 2003), data on threats are typically less accessible, less familiar, and often not formally included in plans (Newburn et al. 2005). As conservation dollars are limited, the challenge is to implement conservation plans identifying large numbers of biologically important areas effectively and efficiently. Protecting areas which are not threatened, or for which conservation value will not endure even with conservation action, is not a wise investment

of conservation resources (Bottrill et al. 2008; Bottrill et al. 2009). I examined two statewide conservation plans for Wisconsin, and evaluated the threat to and vulnerability of each priority area in each plan. I focused on threat from current and projected future housing development because housing development is the major cause of ongoing habitat loss and degradation in Wisconsin (Radeloff et al. 2005). I calculated vulnerability as the proportion of each priority area not currently within a protected area boundary or tribal reservation. I found that most (54-73%) priority areas were highly vulnerable to future threat, and 18% were already highly threatened by housing development. 25-34% of priority areas merit immediate conservation attention, as they are both highly vulnerable and highly threatened. Existing conservation investments were highly threatened in 8-9% of priority areas. Conversely, 20-26% of priority areas are highly vulnerable yet face low threat, likely allowing time for new, large-scale conservation initiatives to succeed. Because of the great variation in vulnerability to and threat from existing and future housing development, the framework I developed can 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. This work is now published in Landscape and Urban Planning (Carter et al. 2014b).

In Chapter 3, I evaluated implementation of conservation plans to date, and identified environmental, socio-economic, and institutional factors associated with recent, successful plan implementation efforts. Opportunities for conservation action are shaped by the human societies in which we live (Cowling & Wilhelm-Rechmann 2007; Game et al. 2011). Socio-economic, institutional, and political factors are known to influence implementation success, but are rarely incorporated into plans (Lerner et al. 2006). I assessed implementation of four conservation plans, and asked which factors explained implementation of the most recent (2008) plan. I found

that implementation begins before plans are completed, continues for decades, and involves multiple agencies and organizations. 45% of lands inside plan boundaries are currently protected, compared to 5% of lands outside plans. Key factors explaining successful implementation efforts of the 2008 plan were 1) prior successful land protection efforts, demonstrating agency (dominantly) and broader-based support for land protection from partners, local government, and the public, 2) having agency authorization for land protection in place prior to plan completion, and 3) the presence of open water. The latter two factors are both priorities in the agency's land protection policy. My findings demonstrate the importance of considering institutional and policy factors in developing conservation plans, so that plans are more likely to highlight actual on-the-ground opportunities for implementation of conservation action. I am currently preparing this work for submission to Conservation Letters.

Significance and implications for future planning initiatives

As human populations continue to grow, so does the challenge of conserving earth's biodiversity. Funding for conservation is limited, and easily diverted to many other worthy causes. Thus the need for effective and efficient conservation solutions is great. Systematic conservation planning has generated much information that can provide answers to the questions of what to conserve, where, and when. Important questions remain, however, including whether conservation plans are in fact influencing conservation actions (Knight et al. 2008), whether areas protected were indeed under threat (Joppa & Pfaff 2009; Scott et al. 2001), and whether the factors typically considered in developing plans are the key information needed to enable implementation to occur (Cowling & Wilhelm-Rechmann 2007). In my dissertation, I began to address these questions using Wisconsin as a study area and land protection as the key evaluation metric. In the process, I contributed to the field of conservation planning, developed new

approaches for analyzing plan effectiveness, identified considerations beyond the resource which influence implementation effectiveness, and generated information that I hope will be applicable and helpful to a broad audience of practitioners, planners, policy makers, and researchers interested in bridging the planning-implementation gap.

My work included important advancements in science and methodologies on the effectiveness of conservation planning while using straightforward approaches and publicly available data such that analyses can be replicated in other locations and modified to address alternate or additional location-specific conservation concerns. Scientifically, my work has helped to broaden the field of conservation planning by supporting a shift of the research focus away from the development of more technically complex plans and toward quantitative evaluations of what plans are able to achieve and why. If the field of conservation planning is to persist, biologists must demonstrate that the plans we write are facilitating and focusing conservation actions in areas identified in plans. If not, the multiple years and hundreds of thousands of dollars expended in developing each new conservation plan (Groves et al. 2002) may be better spent in other ways.

Methodologically, I focused on straightforward approaches to evaluation that could be applied by researchers and practitioners alike. In chapter 1, I quantitatively evaluated the association between specific conservation plans and subsequent conservation outcomes. In chapter 2, I developed a flexible methodology for applying publically available, nationwide data on a major conservation threat to biologically-based conservation plans. This methodology acknowledges that agencies and other organizations have invested substantial time and effort in developing conservation plans. Stakeholders and staff expect that the plans will be used, and their use may be mandated by law. Thus, we provided a much needed approach for improving the utility of existing plans. In Chapter 3, I performed the first quantitative evaluation of which I am aware of

1) patterns of plan implementation over long time frames (50+ years) and 2) socio-economic, institutional, and environmental factors that may explain implementation success. In the process, I developed conceptual models of the plan implementation and land protection processes that may assist conservation researchers and planners in a variety of settings.

I hope that the greatest contribution of my work will be to assist planners, managers, and policy makers in achieving better conservation outcomes by helping them to:

- Understand the potential influence of new plans on future actions, in light of past planning efforts, existing policies, and likely future funding
- Increase the conservation effectiveness of existing plans by applying a straightforward framework for prioritizing among numerous identified priority areas within existing plans based on current and projected future threats and vulnerabilities
- Improve the feasibility of future conservation plans by highlighting specific institutional and policy factors that can be considered in plan development to increase the likelihood of successful implementation.

In addition, there are a number of more general take-home messages that emerged from key findings in my dissertation work that may be relevant to future planning efforts. None are new, nor complicated. Rather, my work provided quantitative analyses to support what others have observed during the course of planning and attempting to implement individual conservation projects.

First, the effort expended in a planning process should be proportional to the amount of new information that the plan will provide. I found that there is substantial overlap in broad scale plans over time. 90% of the priority areas in the most recent conservation plan for Wisconsin

overlap with priority areas in a previous plan (Chapter 1). Further, in many cases priority areas in current plans consist almost entirely of lands that are already protected (Chapter 2). Not unwisely, new plans build on previous plans and on past conservation achievements. However, current planning processes should reflect the large body of information gained through the development of previous plans. Taking the time at the outset of the planning process to clarify and specify what *new* information the new plan will provide can help focus, tailor, and likely expedite, the planning process.

Second, planning processes can be improved by more explicitly considering plan goals. The primary goal of most published conservation plans is the identification of priority sites for conservation action (Knight et al. 2008). However this was not the sole goal for any of the four of the plans I studied (Chapter 1). Additional, and perhaps more important, goals included generating funding for land protection and increasing conservation knowledge and support among stakeholders and the public (J. Pohlman, *pers. comm.*, T. Bergeson, *pers. comm.*). Different goals lend themselves to different planning timeframes and processes, and to the involvement of different stakeholders. For example, a plan being completed largely to meet federal requirements for a modest federal grants program may benefit from the involvement of specific organizations likely to be eligible for future grants from the program. Similarly, plans whose goals include building support for state conservation funding programs should include individuals and organizations active in state politics, and produce products geared toward use in public and political arenas (Pierce et al. 2005).

Third, ‘everything’ cannot be a priority. The number of priority areas in the plans I studied ranged from 155 to 255 (Chapters 1, 2). There are simply not enough resources to support concurrent implementation (be it through land protection, management, or restoration) of so

many priority areas. Prioritization is necessary when funds are limited and plans include hundreds of priorities (Bottrill et al. 2008; Bottrill et al. 2009). An objective, transparent prioritization approach can help build agency, partner, political, and public support for short-term implementation priorities, while setting the stage for longer term conservation efforts.

Fourth, broad scale, long-term plans are implemented through localized, short-term actions. I found no clear relationship between broad-scale plans and subsequent actions (Chapter 1). However, the approval of local projects was strongly linked to land protection action almost immediately (Chapter 1). Local projects succeed when committed individuals (or conservation champions, *sensu* Knight et al. 2011a) initiate and generate support for the effort. Thus broad-scale plans may be implemented most effectively when 1) the planning process includes developing project 'champions' at the local level (Knight et al. 2011a), and 2) planning agencies commit to implementing a small number of local projects identified in the plan within the course of a few years (see Chapter 1). Ideally, this occurs when agencies commit to follow-up implementation plans that both authorize funding and resources for specific local projects identified in the plan and hold the agency accountable for making measurable progress toward completing those projects.

Fifth, evaluating past efforts can elucidate important drivers of conservation action. For example, I found that the agency studied tends to buy proportionately greater amounts of forests and wetlands than are identified in plans, and fewer grasslands (Chapter 1). Multiple factors are likely behind these land protection patterns. For example, forests are less expensive than grasslands, they generally generate greater economic returns, and many people prefer to recreate in them. In addition, there are established federal programs that fund forest protection. Conversely, local governments and policies may strongly discourage the removal of agricultural

lands from active agriculture. Without a change in these underlying factors, a new plan is unlikely to change land protection patterns.

Sixth, conservation gains are best explained not by conservation value, but by institutional policies and past land protection successes (Chapter 3). As a result, opportunities for real gains in the short term (e.g., within 5 years) lie where biological priorities in plans align with both agency policies and past conservation successes. Consideration of relevant institutional information (land protection records, agency policy priorities) at the outset of a planning process can help produce a new generation of plans for which near term implementation success is more likely.

Finally, conservation takes time, often much longer than planners and stakeholders anticipate. A decade or more may be needed for new land protection projects to get off the ground (Chapter 1). To avoid stakeholder burnout and public dissatisfaction, expectations need to be managed during the planning process. On a more positive note, once projects are initiated, actions may continue for decades (Chapters 1, 3). Thus plans written today may well influence conservation actions into the next century. Planners and practitioners should be proud of such a legacy.

Conservation biology has been criticized as an academic endeavor which has had little impact on real world activities (Whitten et al. 2001). Given the small proportion of conservation plans effectively implemented to date (Knight et al. 2008), the same might be said of conservation planning. My project has provided quantitative assessments of plan influence and implementation and of factors associated with implementation success, as well as methods for improving the effectiveness of existing plans. It is my hope that planners, practitioners, and policy makers can use this information to help identify where and under what circumstances

conservation practitioners are most likely to be successful in their conservation actions, develop a new generation of more integrated and feasible conservation plans, and ultimately improve the effectiveness of long term conservation efforts.

References

Ahnstrom, J., J. Hockert, H. L. Bergea, C. A. Francis, P. Skelton, and L. Hallgren. 2009. Farmers and nature conservation: What is known about attitudes, context factors and actions affecting conservation? Renewable Agriculture and Food Systems 24:38-47.

Alexander, E. 2000. Rationality revisited: planning paradigms in a post-postmodernist perspective. Journal of Planning Education and Research 19:242-256.

Alexander, E. 1998. Doing the 'impossible': notes for a general theory of planning. Environment and Planning B 25:667-680.

Bengston, D. N., J. O. Fletcher, and K. C. Nelson. 2004. Public policies for managing urban growth and protecting open space: policy instruments and lessons learned in the United States. Landscape and Urban Planning 69:271.

Bottrill, M. C., L. N. Joseph, J. Carwardine, M. Bode, C. N. Cook, E. T. Game, H. Grantham, S. Kark, S. Linke, E. McDonald-Madden, R. L. Pressey, S. Walker, K. A. Wilson, and H. P. Possingham. 2008. Is conservation triage just smart decision making? Trends in Ecology & Evolution 23.

Bottrill, M. C., L. N. Joseph, J. Carwardine, M. Bode, C. N. Cook, E. T. Game, H. Grantham, S. Kark, S. Linke, E. McDonald-Madden, R. L. Pressey, S. Walker, K. A. Wilson, and H. P.

Possingham. 2009. Finite conservation funds mean triage is unavoidable. Trends in Ecology & Evolution 24:183.

Bottrill, M. C., M. Mills, R. L. Pressey, E. T. Game, and C. Groves. 2012. Evaluating Perceived Benefits of Ecoregional Assessments. Conservation Biology 26:851-861.

Bottrill, M. C., and R. L. Pressey. 2012. The effectiveness and evaluation of conservation planning. Conservation Letters 5:407.

Branton, M., and J. S. Richardson. 2011. Assessing the Value of the Umbrella-Species Concept for Conservation Planning with Meta-Analysis. Conservation Biology 25:9.

Carter, S. K., N. S. Keuler, A. M. Pidgeon, and V. C. Radeloff. 2014a. Evaluating the influence of conservation plans on land protection actions in Wisconsin, USA. Biological Conservation 178:37-49.

Carter, S. K., J. D. Pohlman, T. L. Bergeson, C. M. Hamilton, A. M. Pidgeon, and V. C. Radeloff. 2014b. Improving the utility of existing conservation plans using projected housing development. Landscape and Urban Planning 126:10-20.

Cowling, R. M., R. L. Pressey, R. Sims-Castley, A. le Roux, E. Baard, C. J. Burgers, and G. Palmer. 2003. The expert or the algorithm? - comparison of priority conservation areas in the Cape Floristic Region identified by park managers and reserve selection software. Biological Conservation 112:147.

Cowling, R. M., and A. Wilhelm-Rechmann. 2007. Social assessment as a key to conservation success. Oryx 41:135-136.

Fausch, K. D., C. E. Torgersen, C. V. Baxter, and H. W. Li. 2002. Landscapes to riverscapes: Bridging the gap between research and conservation of stream fishes. Bioscience 52:483-498.

Game, E. T., G. Lipsett-Moore, R. Hamilton, N. Peterson, J. Kereseka, W. Atu, M. Watts, and H. P. Possingham. 2011. Informed opportunism for conservation planning in the Solomon Islands. Conservation Letters 4:38-46.

Groves, C. R., D. B. Jensen, L. L. Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson. 2002. Planning for biodiversity conservation: Putting conservation science into practice. Bioscience 52:499.

Joppa, L. N., and A. Pfaff. 2009. High and Far: Biases in the Location of Protected Areas. Plos One 4:e8273.

Kapos, V., A. Balmford, R. Aveling, P. Bubb, P. Carey, A. Entwistle, J. Hopkins, T. Mulliken, R. Safford, A. Stattersfield, M. Walpole, and A. Manica. 2009. Outcomes, not implementation, predict conservation success. Oryx 43:336-342.

Kideghesho, J. R., E. Roskaft, and B. P. Kaltenborn. 2007. Factors influencing conservation attitudes of local people in Western Serengeti, Tanzania. Biodiversity and Conservation 16:2213-2230.

Knight, A. T., R. M. Cowling, A. F. Boshoff, S. L. Wilson, and S. M. Pierce. 2011a. Walking in STEP: Lessons for linking spatial prioritisations to implementation strategies. Biological Conservation 144:202-211.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell. 2008. Knowing but not doing: Selecting priority conservation areas and the research-implementation gap. Conservation Biology 22:610.

Knight, A. T., H. S. Grantham, R. J. Smith, G. K. McGregor, H. P. Possingham, and R. M. Cowling. 2011b. Land managers' willingness-to-sell defines conservation opportunity for protected area expansion. Biological Conservation 144:2623-2630.

Lerner, J., B. Cochran, and J. Michalak. 2006. Conservation Across the Landscape: A Review of the State Wildlife Action Plans. Defenders of Wildlife, Washington D.C.

Lerner, J., J. Mackey, and F. Casey. 2007. What's in Noah's wallet? Land conservation spending in the United States. Bioscience 57:419-423.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature 405:243.

Moilanen, A., K. A. Wilson, and H. P. Possingham 2009. Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford; New York.

Newburn, D., S. Reed, P. Berck, and A. Merenlender. 2005. Economics and land-use change in prioritizing private land conservation. Conservation Biology 19:1411.

Pierce, S. M., R. M. Cowling, A. T. Knight, A. T. Lombard, M. Rouget, and T. Wolf. 2005. Systematic conservation planning products for land-use planning: Interpretation for implementation. Biological Conservation 125:441.

Radeloff, V. C., F. Beaudry, T. M. Brooks, V. Butsic, M. Dubinin, T. Kuemmerle, and A. M. Pidgeon. 2013. Hot moments for biodiversity conservation. Conservation Letters 6:58-65.

Radeloff, V. C., R. B. Hammer, and S. I. Stewart. 2005. Rural and suburban sprawl in the US Midwest from 1940 to 2000 and its relation to forest fragmentation. Conservation Biology 19:793.

Sanderson, E. W., M. Jaiteh, M. A. Levy, K. H. Redford, A. V. Wannebo, and G. Woolmer. 2002. The human footprint and the last of the wild. Bioscience 52:891-904.

Sarkar, S., R. L. Pressey, D. P. Faith, C. R. Margules, T. Fuller, D. M. Stoms, A. Moffett, K. A. Wilson, K. J. Williams, P. H. Williams, and S. Andelman. 2006. Biodiversity conservation planning tools: Present status and challenges for the future. Annual Review of Environment and Resources 31:123.

Schipper, J., J. S. Chanson, F. Chiozza, N. A. Cox, M. Hoffmann, V. Katariya, J. Lamoreux, A. S. L. Rodrigues, S. N. Stuart, H. J. Temple, J. Baillie, L. Boitani, T. E. Lacher, Jr., R. A. Mittermeier, A. T. Smith, D. Absolon, J. M. Aguiar, G. Amori, N. Bakkour, R. Baldi, R. J. Berridge, J. Bielby, P. A. Black, J. J. Blanc, T. M. Brooks, J. A. Burton, T. M. Butynski, G. Catullo, R. Chapman, Z. Cokeliss, B. Collen, J. Conroy, J. G. Cooke, G. A. B. da Fonseca, A. E. Derocher, H. T. Dublin, J. W. Duckworth, L. Emmons, R. H. Emslie, M. Festa-Bianchet, M. Foster, S. Foster, D. L. Garshelis, C. Gates, M. Gimenez-Dixon, S. Gonzalez, J. F. Gonzalez-Maya, T. C. Good, G. Hammerson, P. S. Hammond, D. Happold, M. Happold, J. Hare, R. B. Harris, C. E. Hawkins, M. Haywood, L. R. Heaney, S. Hedges, K. M. Helgen, C. Hilton-Taylor, S. A. Hussain, N. Ishii, T. A. Jefferson, R. K. B. Jenkins, C. H. Johnston, M. Keith, J. Kingdon, D. H. Knox, K. M.

Kovacs, P. Langhammer, K. Leus, R. Lewison, G. Lichtenstein, L. F. Lowry, Z. Macavoy, G. M. Mace, D. P. Mallon, M. Masi, M. W. McKnight, R. A. Medellin, P. Medici, G. Mills, P. D. Moehlman, S. Molur, A. Mora, K. Nowell, J. F. Oates, W. Olech, W. R. L. Oliver, M. Oprea, B. D. Patterson, W. F. Perrin, B. A. Polidoro, C. Pollock, A. Powel, Y. Protas, P. Racey, J. Ragle, P. Ramani, G. Rathbun, R. R. Reeves, S. B. Reilly, J. E. Reynolds, III, C. Rondinini, R. G. Rosell-Ambal, M. Rulli, A. B. Rylands, S. Savini, C. J. Schank, W. Sechrest, C. Self-Sullivan, A. Shoemaker, C. Sillero-Zubiri, N. De Silva, D. E. Smith, C. Srinivasulu, P. J. Stephenson, N. van Strien, B. K. Talukdar, B. L. Taylor, R. Timmins, D. G. Tirira, M. F. Tognelli, K. Tsytsulina, L. M. Veiga, J.-C. Vie, E. A. Williamson, S. A. Wyatt, Y. Xie, and B. E. Young. 2008. The status of the world's land and marine mammals: Diversity, threat, and knowledge. Science 322:225.

Scott, J. M., F. W. Davis, R. G. McGhie, R. G. Wright, C. Groves, and J. Estes. 2001. Nature reserves: Do they capture the full range of America's biological diversity? Ecological Applications 11:999.

Spring, D. A., O. Cacho, R. Mac Nally, and R. Sabbadin. 2007. Pre-emptive conservation versus "fire-fighting": A decision theoretic approach. Biological Conservation 136:531-540.

Starkey, K., and P. Madan. 2001. Bridging the relevance gap: Aligning stakeholders in the future of management research. British Journal of Management 12:S3-S26.

Stephanson, S. L., and M. B. Mascia. 2014. Putting people on the map through an approach that integrates social data in conservation planning. Conservation biology: 28:1236-1248.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science 277:494-499.

Whitten, T., D. Holmes, and K. MacKinnon. 2001. Conservation biology: a displacement behavior for academia? Conservation Biology 15:1.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. Bioscience 48:607.

Wilson, K., R. L. Pressey, A. Newton, M. Burgman, H. Possingham, and C. Weston. 2005. Measuring and incorporating vulnerability into conservation planning. Environmental management 35:527.

Wilson, K. A., E. C. Underwood, S. A. Morrison, K. R. Klausmeyer, W. W. Murdoch, B. Reyers, G. Wardell-Johnson, P. A. Marquet, P. W. Rundel, M. F. McBride, R. L. Pressey, M. Bode, J. M. Hoekstra, S. Andelman, M. Looker, C. Rondinini, P. Kareiva, M. R. Shaw, and H. P. Possingham. 2007. Conserving biodiversity efficiently: What to do, where, and when. Plos Biology 5:1850.

Chapter 1: Evaluating the influence of conservation plans on land protection actions in Wisconsin, USA

Abstract

Conservation plans are a common management tool, but are rarely evaluated for their influence on conservation actions. We assessed four statewide conservation plans and 371 local land protection projects developed by a state land management agency in the United States. We asked whether completion of statewide plans and approval of local projects were associated with changes in the amount, location, and landcover composition of subsequently protected lands. We found a weak relationship between statewide plans and land protection actions. Completion of two of four plans was associated with an increase in land protection statewide or within plan boundaries. However, 58% of lands protected within 20 years of plan completion were outside plan boundaries. Further, the proportion of statewide land protection activity focused inside plan boundaries was lower or not different after plan completion for three of four plans. Conversely, for > 90% of local land protection projects, most land protection occurred after formal project approval compared to before, with much of that activity occurring almost immediately. Forests and wetlands were protected more often than planned, while pasture and crop lands were protected less often than planned. We suggest that conservation plans are most likely to influence land protection actions when dependable, multi-year funding for land protection is present, when public, institutional, and political support for implementation are strong; and when agencies commit to an implementation strategy that links broad-scale plans to specific, local land protection projects and is actionable within the framework of existing administrative rules governing agency land protection.

Introduction

Conservation plans are a common management tool, but there has been little comprehensive evaluation of their effectiveness in influencing subsequent conservation actions (Bottrill & Pressey 2012). Plans are developed by universities and local, state, national, and international agencies and conservation organizations to voluntarily identify conservation priorities, fulfill legal obligations, or be eligible for funding programs (e.g., Wildlife Action Plans in the United States (US), US Fish and Wildlife Service 2006). Accordingly, some plans are tied explicitly to funding for implementation, while many others are not. Additionally, some plans are comprehensive (i.e., biodiversity conservation is the goal), while others focus on specific regions, habitat types, taxonomic groups, or species. Despite such differences in conservation plans, nearly all plans are intended to guide subsequent conservation actions, often focusing on land protection, and require significant commitments of staff and resources (Bottrill & Pressey 2012; Bottrill et al. 2012). Conservation is a key driver of land protection efforts. However, the missions of agencies and organizations implementing conservation plans, and thus the drivers behind their land protection efforts, often include other goals as well (e.g., resource extraction, provision of recreational opportunities, preservation of scenic and historic sites, Pressey 1994). Thus, an important question is whether comprehensive conservation plans are effective in influencing subsequent land protection activities.

The effectiveness of conservation plans in influencing subsequent conservation actions can be evaluated in numerous ways. One approach is to survey people who developed or were responsible for implementing plans. Qualitative surveys suggest that potential benefits of plans are broad, including influences to natural, financial, social, human, and institutional capital (Bottrill & Pressey 2012; Bottrill et al. 2012). However, many published plans (67%) are not

implemented, and few implemented actions (13%) are considered highly effective (Knight et al. 2008). Examples of successful plan implementation exist, in which lands or waters identified as priorities were subsequently protected (an institutional capital outcome) and conservation awareness and support for action among stakeholders increased (a human capital outcome, Fernandes et al. 2005; Gleason et al. 2010). In other cases plan implementation was successful by some human and social capital metrics (e.g., raising conservation awareness, stakeholder participation in project workshops), but achieved only mixed success or failed by institutional capital metrics (e.g., mainstreaming of plan products into agency land-use planning decisions, incorporating plan priorities into agency initiatives, Knight et al. 2011a). In general, the most commonly reported benefits of conservation plans are human, institutional, and social capital outcomes; positive natural and financial outcomes are reported less frequently (Bottrill & Pressey 2012; Bottrill et al. 2012). We build on these qualitative assessments of plan implementation by quantitatively evaluating an institutional and a natural capital outcome from multiple conservation plans: the allocation of institutional resources to priority areas in plans and the representation of biodiversity assets within newly protected areas. We based our evaluation on land records commonly collected by agencies and organizations that protect land, to facilitate application of this approach in other locations.

In our evaluation, we considered three goals of conservation plans and how well they are realized in subsequent conservation actions: 1) the amount of land protected, 2) the location of protected lands, and 3) the vegetation type of protected lands. Comprehensive planning efforts often span multiple years and involve numerous meetings with stakeholders and the public (Bottrill & Pressey 2012; Groves et al. 2002). As a result, the planning effort may raise conservation awareness (Bottrill & Pressey 2012; Bottrill et al. 2011), potentially increasing public support for

conservation action (Fernandes et al. 2005; Knight et al. 2011a) resulting in an increase in the amount of land protected. Conservation planning may also influence where land is protected by focusing land protection efforts inside plan boundaries (Margules & Pressey 2000). Finally, conservation planning may influence which landcover types are protected. Systematic conservation planning includes an assessment of how well existing protected areas meet conservation goals (Groves et al. 2002; Margules & Pressey 2000). Landcover is often used as a surrogate for biodiversity (e.g., Knight et al. 2011b), and thus plans typically identify gaps in landcover representation within the existing protected area network. A plan which finds, for example, that grasslands are currently under-represented, might prioritize grassland conservation and stimulate protection of grasslands both inside and outside of plan boundaries.

We focused our evaluation on plans developed by land management agencies and their subsequent land protection activities. Land management agencies in the US have protected much of the existing protected area network (Conservation Biology Institute 2012) and frequently develop conservation plans to guide their operations, including land protection. Agency plans, however, are rarely published in the peer-reviewed literature and thus are rarely evaluated (e.g., Knight et al. 2008).

Key components of effective processes for implementing conservation plans include stakeholder involvement, empowering individuals and institutions to act, securing high-level support for action, evaluating and monitoring outcomes to ensure accountability and inform future actions, and mainstreaming planning products into the policies and practices of land planning and management agencies (Knight et al. 2006, 2011a; Martin et al. 2012; Pierce et al. 2005). When considering plan implementation specifically in terms of land protection, important considerations include funding, support, and legal authority for protection; land ownership

patterns; and likely land availability (Fernandes et al. 2005; Gleason et al. 2010; Knight et al. 2011b).

Implementation of conservation plans via land protection actions in an agency context may involve multiple steps (Fig. 1). Important considerations include the impetus for plan development, the degree to which plan goals align with the agency's mission, support and funding for planning and implementation, public and stakeholder involvement, and laws, administrative rules, and policies governing land protection actions (Fig. 1). Public involvement in conservation planning and land protection actions is a major emphasis of publicly funded agencies, is often mandated by law (e.g., US National Environmental Policy Act of 1969), and often contributes to the multi-year timeframes needed for plan development and approval.

Existing laws, administrative rules, and policies governing land protection at national, state, and local scales may mediate the potential impact of any individual plan on subsequent land protection patterns. For example, federal laws may prioritize protection of individual parcels that both provide recreational opportunities and contribute to conservation of endangered species (e.g., Title 16 U.S. Code §460k-1). State administrative rules may prioritize acquisitions within existing land protection projects over new projects (e.g., Wis. Admin. Code NR §1.40(2)(a), Appendix A). Federal policies (e.g., the National Wildlife Refuge System Draft Strategic Growth Policy, US Fish and Wildlife Service 2014) may define nationwide acquisition priorities for federal agencies. Such laws, administrative rules, and policies may also promulgate past patterns of land protection despite plans which may identify other priorities. For example, if past land protection reflected a pattern of residual reservation, in which lands of low economic value received the greatest protection (Joppa & Pfaff 2009; Pressey 1994; Scott et al. 2001), these patterns are more likely to continue if laws, administrative rules, or policies facilitate protection

of landcover types of low economic value (e.g., if land price per unit area is a criteria for evaluating land acquisitions). While laws, administrative rules and formally approved policies are subject to change, substantive changes tend to be infrequent, occurring much less often than the development of new conservation plans.

A difficulty in evaluating the influence of conservation plans on subsequent conservation actions is that plans are usually implemented incrementally (Bottrill & Pressey 2012; Pressey et al. 2013). Further, conservation actions such as land protection, land management, and habitat restoration take time to implement and to become apparent on the landscape. We addressed this challenge by choosing a study site with a long history of conservation planning and more than a century of land protection records.

Our overarching question was whether priorities identified in comprehensive conservation plans developed by land management agencies were reflected in their subsequent land protection activities. We examined four statewide conservation plans for Wisconsin, US, hundreds of individual (local) land protection projects within the state, and over a century of agency land protection records. We had three objectives. First, we asked whether planning efforts were associated with changes in land protection activity a) across the state, b) within statewide plan boundaries, and c) within individual (local) land protection projects. Second, we asked if the proportion of land protection focused inside plan boundaries changed after plan completion. Finally, we asked whether the landcover composition inside plan boundaries was reflected in the landcover composition of subsequently protected lands. We discuss implications of our findings for implementing conservation plans via land protection actions in a land management agency context and suggest strategies for facilitating plan implementation that may apply in other contexts and locations as well.

Methods

Wisconsin (~145,000 km^2) is located at the confluence of the Northern Forests, Eastern Temperate Forests, and Great Plains in the north-central US (Commission for Environmental Cooperation 1997). Northern hardwood forests dominate northern Wisconsin, while southern Wisconsin has largely been converted to agriculture (Rhemtulla et al. 2007). Wisconsin is biologically diverse, with over 150 wildlife species of conservation concern (Wisconsin Department of Natural Resources 2005). Major biodiversity threats include habitat loss, invasive species, and pollution (Wisconsin Department of Natural Resources 2005).

Data

We examined four comprehensive statewide plans completed in 1939, 1964, 2004, and 2008 (Table 1, Appendix B). All were expert-based, had conservation only or dual conservation and recreation goals, and were led by or developed in close collaboration with the Wisconsin Department of Natural Resources. Priority area criteria were primarily biological (e.g., high-quality natural areas, important populations of rare species), but also included recreation, water quality, scenic, scientific, geologic, and historic value (Appendix B). Plans included an average of 211 priority areas (range 155-255) covering 22% of the state (range 12%-30%).

We defined total protected lands as all lands protected for conservation or recreation purposes via acquisition or easement or within tribal reservations (Conservation Biology Institute 2012; National Conservation Easement Database 2013; Wisconsin Department of Natural Resources 2013a, 2014a). Total protected lands encompassed 27,769 km^2, and included county, state, and national forests.

Wisconsin Department of Natural Resources land protection data included lands protected by the agency or with state funds between 1876 and 2013 (17,437 records). Each land protection record included the date, size, protection type, and cost. We combined protection types (primarily fee simple (87%) and easement (12%)) for analysis, as suggested by agency personnel.

Individual local land protection projects (e.g., proposed state parks) are initiated through a formal planning and approval process governed by agency policy (i.e., Manual Code 2105.2, Wisconsin Department of Natural Resources 2003), and have a formal boundary within which multiple parcels are generally acquired over time. Each land protection record between 1938 and 2011 included the associated land protection project, the year the project was approved, and the total area within the project boundary. We considered only projects with a boundary larger than 0.17 km^2 (average 19.6 km^2, range 0.17-930.7 km^2), as smaller projects were primarily for buildings or public access.

We used remotely-sensed landcover data with a spatial resolution of 30 m (Fry et al. 2011). We considered gross domestic product for the US or Wisconsin (in real US dollars, Bureau of Economic Analysis 2013a, 2013b) as an indicator of the general state of the economy. We considered funds from the two major state programs funding land protection for conservation and recreation purposes in Wisconsin (Theobald & Robbins 1970, 1973, 1977, 1985; Wisconsin Legislative Reference Bureau 2011; A. Runyard, *pers. comm.*), which comprise >90% of state funding for land protection in Wisconsin (Wisconsin Department of Natural Resources 2014a). We used funds from the federal Land and Water Conservation Fund that were granted to states for land protection (US Department of the Interior 2010, 2011, 2012; Vincent 2010) as an indicator of federal conservation funding. We adjusted land cost and state and federal conservation funding prior to 2013 to 2013 dollars using the annual Consumer Price Index for

Urban Wage Earners and Clerical Workers (US Bureau of Labor Statistics 2013; US Bureau of the Census 1975).

Analyses

We analyzed whether plan completion was associated with the amount of land protected statewide, within statewide conservation plan boundaries, and within individual (local) land protection projects. We considered three response variables: 1) value of land protected (cost to acquire, in US dollars), 2) area of land protected (km^2), and 3) number of land protection transactions.

For the first two spatial scales, we used multiple linear regression and considered only lands protected from 1900 to 2012 for which spatial data were available (15,740 records). We log- or square root-transformed response variables to improve normality, and log-transformed gross domestic product when needed to improve linearity based on visual analysis of the plotted variables. We checked regression residuals for temporal autocorrelation using the autocorrelation function (acf). If we detected a significant pattern of autocorrelation, we fit a model that appropriately accounted for the observed lack of independence.

Statewide, we regressed response variables against plan completion dates, gross domestic product, and state and federal funding for land protection. We modeled plan effect as zero before plan completion and one thereafter.

Within statewide conservation plan boundaries, we regressed response variables against whether each statewide plan was in place, gross domestic product, and state and federal funding for land protection. We considered only data for the twenty years before and after completion of each plan, as expanding housing development and changing land use in Wisconsin (Radeloff et al.

2005) suggest that plans older than 20 years were unlikely to be considered current guides for land protection. We analyzed only 10 years of pre-plan data for the 1939 plan, as gross domestic product was only available from 1929. Only 9 and 5 years of post-plan data were available for the 2004 and 2008 plans, respectively. For analyses of land protected statewide and within 1939 and 1964 plan boundaries, we used US gross domestic product, as Wisconsin gross domestic product was only available back to 1963, and both were highly correlated thereafter (Pearson correlation, r=0.996).

At the individual project scale, we used chi-squared tests to compare the proportion of land protection projects for which the majority of land protection activity occurred before versus after formal project approval. We limited analysis to projects approved between 1948 and 2002 to ensure at least ten years of pre- and post-project approval data for all projects.

We used t-tests, assuming unequal variance, to compare the proportion of land protection activity (value of lands protected, area of land protected, and number of land protection transactions) occurring within statewide plan boundaries in the 20 years before versus (up to) 20 years after plan completion.

Finally we compared the landcover composition of 1) all lands, and 2) unprotected lands only inside the two recent plans with the composition of lands protected since completion of each plan. We also calculated the composition of 1) all protected lands statewide (to assess past land protection efforts), and 2) all unprotected lands statewide (to assess the availability of individual landcover types). We conducted all statistical analyses in R (R Core Team 2013).

Results

Do plans influence how much land is protected?

Statewide, the total annual value of land protected increased substantially beginning about 1960, a decade in which federal and state funding programs for land protection began (Fig. 2). Total annual area of land protected and number of land protection transactions increased substantially beginning about two decades earlier, coinciding with the 1939 conservation plan (Fig. 2). Two of three metrics of statewide land protection activity increased significantly upon completion of two of the four statewide plans (Appendix C). The value and area of land protected statewide increased significantly upon completion of the 1939 plan ($p<0.001$ for both metrics). The area of land protected ($p=0.002$) and number of land protection transactions ($p=0.04$) statewide also increased significantly upon completion of the 2008 plan.

Within statewide conservation plan boundaries, land protection activity started in the early 1900s and continued through 2013 for each plan (Fig. 3). We detected a significant change in land protection activity within plan boundaries upon plan completion for only one of the four plans, and for only a single metric: more land protection transactions occurred after completion of the 2008 plan ($p=0.002$, Appendix D).

At the local scale of individual land protection projects, significantly more projects had greater land protection activity occurring after formal project approval compared to before (for 94.5%, 90.9%, and 93.8% of projects, the majority of the value of land protected, area of land protected, and number of land protection transactions, respectively, occurred after formal project approval, $p<0.001$ for all metrics, Appendix E). Further, about half of all land protection activity on projects (50.1% of the value of land protected, 59.3% of the area protected, and 50.1% of land

protection transactions) was concentrated within the first five years following project approval (Fig. 4).

Do plans influence where land is protected?

Land protection in the 20 years after plan completion included many parcels well outside of plan boundaries for all plans (Fig. 5). The proportion of land protection activity focused within plan boundaries varied dramatically for all plans prior to about 1940 (Fig. 6), likely due to a lower overall level of land protection activity (Fig. 3). Only a single plan/response variable combination (of 12 tested) showed a significant increase in the proportion of land protection activity occurring within plan boundaries after plan completion (proportion of land protection transactions inside the 2008 plan: before: 0.59, after: 0.63, $p=0.04$, Appendix F). There was also no clear pattern of increasing concentration of land protection activity within plan boundaries over longer time periods following plan completion (Fig. 6). In contrast, the proportion of total land protection activity occurring within plan boundaries decreased after plan completion for two of the three response variables for the 1939 plan (proportion of total area of land protected: before: 0.70, after: 0.27, $p<0.001$; proportion of land protection transactions: before: 0.65, after: 0.38, $p=0.003$), and for one of the three response variables for the 1964 plan (proportion of land protection transactions: before: 0.39, after: 0.32, $p=0.02$, Appendix F).

Do plans influence what kind of land is protected?

Land protection following the 2004 and 2008 plans was higher than planned for forests and wetlands, and lower than planned for pasture/hay and crop lands (Table 2). Deciduous forests dominated the 2013 protected area network (43% of existing protected area) and were the dominant landcover type in both plans (29% and 36% of the 2004 and 2008 plans, respectively). In subsequent years, the Wisconsin Department of Natural Resources continued to protect

deciduous forests more than any other landcover type and in higher proportions than identified in plans (44% and 45% of all lands protected since 2004 and 2008, respectively). Wetlands were the second most common landcover type in the 2013 protected area network (28% of existing protected area), and the second or third highest landcover priority in plans (19% and 20% of the 2004 and 2008 plans, respectively). In subsequent years, the agency continued to protect wetlands as the second most common landcover type, and in higher proportions than identified in plans (28% and 29% of lands protected since 2004 and 2008, respectively). In contrast, pasture/hay (important habitat for grassland-dependent wildlife, Renfrew & Ribic 2008) and cultivated crop lands (important as matrix habitat and restoration sites, Sample et al. 1997) together comprised only 4.6% of the 2013 protected area network. Together these two categories represented 32% and 21% of lands in the 2004 and 2008 plans, respectively, and an even higher percentage of the unprotected lands (42% and 34% of unprotected lands in the 2004 and 2008 plans, respectively), yet only comprised 10% of subsequently protected lands. Availability of pasture/hay and crop lands was not limiting (15,324 and 37,172 km^2 unprotected in 2013, respectively).

Discussion

Development of conservation plans is time and resource intensive (Bottrill & Pressey 2012; Groves et al. 2002), raising the importance of evaluating the influence of plans on conservation actions. Evaluation can assess whether planning met its goals, improve accountability, and provide key information needed to improve and adapt future planning initiatives (Bottrill & Pressey 2012; Grantham et al. 2010). We evaluated the influence of plans on subsequent land protection actions in the context of a state land management agency. We found that while comprehensive statewide conservation plans were associated with increased land protection

activity across the state and within plan boundaries in some cases, they generally did not focus land protection efforts within plan boundaries (58% of lands protected within 20 years of plan completion were outside of plan boundaries). Furthermore, the landcover composition of priority areas in statewide plans was only weakly reflected in subsequent land protection activity. Conversely, at the local scale of individual land protection projects, more than 90% of all projects had greater land protection activity occurring after formal project approval compared to before, and half of all activity was concentrated within the first five years following project approval. Funding and institutional, public, and political support for implementation; alignment of plan goals with the agency's mission; and laws, administrative rules, and policies governing land protection actions may mediate the influence of plans on agency land protection actions in Wisconsin and elsewhere. We suggest that conservation plans are most likely to influence land protection actions when dependable, multi-year funding for land protection is present, when public, institutional, and political support for implementation are strong, and when agencies commit to an implementation strategy that both links broad-scale plans to specific, local land protection projects and is actionable within the framework of existing laws, administrative rules, and policies governing agency land protection actions.

Do plans influence how much land is protected?

While conservation plans are commonly perceived to influence institutional investments (Bottrill et al. 2012), we found a weak relationship overall between plans and subsequent land protection actions at broad scales. A quantitative evaluation of multiple species recovery plans also failed to find clear impacts of plans on conservation outcomes (Bottrill et al. 2011). We attempted to account for changes in the overall economy and in conservation funding in our models, and both gross domestic product and state funding for conservation were often associated with changes in

land protection activity (Appendices C, D). Coincidental changes in planning and funding for conservation illustrate their often interconnected nature, but make it difficult to identify effects of a given conservation plan (Ferraro & Pattanayak 2006). For example, completion of the 1964 plan coincided with a rapidly growing economy (Fig. 2d), passage of major federal legislation earmarking federal funds for land protection (i.e., Wilderness Act of 1964 and Land and Water Conservation Fund Act of 1965, Rodgers 1993-1994; Fig. 2e), and creation of a state program for land protection in Wisconsin (Voigt 1962; Fig. 2f). While completion of the 1964 plan was not associated with an increase in any metric of land protection activity, both gross domestic product and state funding for land protection were significantly positively associated with land protection activity both statewide and within the boundaries of the 1964 plan (Appendices C, D).

Our results contrast with two marine planning initiatives, in which planning resulted in rapid and significant increases in protected areas (e.g., the proportion of north central California state waters protected increased from 3.2% to 20% upon implementation of the Marine Life Protection Act Initiative (Gleason et al. 2010); the proportion of the Great Barrier Reef in no-take areas increased from 4.5% to 33% upon plan implementation (Fernandes et al. 2005)). A lack of private landowners and authority for rapid and broad-scale land protection by federal or state authorities in marine environments may have facilitated rapid and successful plan implementation in the marine sites (Fernandes et al. 2005; Gleason et al. 2010). A legal mandate for plan implementation may also have contributed to the success of the California plan, although two previous planning efforts initiated under the same mandate failed (Gleason et al. 2010). Development of several of the plans examined here was required by the state or federal government (Table 1), but implementation was required in only one case (the 2008 plan) and

only for activities funded by the associated federal grants program (in Wisconsin, funds from this program were not used for land protection, T. Bergeson, *pers. comm*.).

In contrast to our findings for statewide plans, the approval of local land protection projects was associated with significantly higher land protection activity inside project boundaries. Administrative rules and policies governing land protection within the agency likely contributed to this finding in two ways. First, administrative rules require that the agency's first priority for land protection be protection of lands inside existing local projects (Wis. Admin. Code NR §1.40, Appendix A). Land acquisition can and does occur outside of project boundaries, but it occurs much less frequently and requires additional levels of approval (Wis. Admin. Code NR §1.41, Appendix A). Second, land protection activity is authorized, and often begins, immediately upon local project approval (land protection activity began within the first five years of project approval for 97% of projects). In contrast, the process from statewide plan to establishment of a new project includes multiple steps and approval processes (Fig. 1), and can take many years (Wisconsin Department of Natural Resources 2003, 2013b). Similar planning processes that include both a strong regional component and a strong local site-based component also exist in other agencies (e.g., US Fish and Wildlife Service National Wildlife Refuge System, D. Granholm, *pers. comm.*) and organizations (e.g., The Nature Conservancy, Bottrill et al. 2012). Associated policies (or, in the case of agencies, laws and administrative rules as well) guiding these planning processes and subsequent land protection transactions may mediate the extent and timing of the influence of broad scale plans on subsequent land protection actions.

Do plans influence where land is protected?

An average of 58% of lands protected within 20 years of plan completion were outside of plan boundaries, possibly reflecting limited lands for sale within plan boundaries, flexibility in

potential conservation sites across the landscape (Pressey et al. 1993), and the breadth of the agency's mission. Landowner willingness-to-sell can substantially constrain conservation opportunities (Knight et al. 2011b), and land protection in our study area requires that landowners are willing to sell. Thus agencies may wisely pursue opportunities to protect land outside plan boundaries that would provide similar conservation or recreation benefits. Lands protected to meet other aspects of the agency's mission or vision (e.g., 'supporting the economy', Wisconsin Department of Natural Resources 2013c) or in accordance with other resource or program-specific plans (e.g., Wisconsin's Forest Legacy Areas, Wisconsin Department of Natural Resources 2012) may have also contributed to the large proportion of lands protected outside the boundaries of comprehensive statewide conservation plans. Land protection efforts of a large land trust (The Nature Conservancy) were concentrated more strongly inside plan boundaries (74% of acquisitions were inside ecoregional plan boundaries, Fisher & Dills 2012), possibly reflecting its more focused mission (i.e., 'to conserve the lands and waters on which all life depends').

The proportion of total land protection activity focused within statewide plan boundaries was lower or not significantly different after plan completion for three of the four plans. Fisher & Dills (2012) also found no evidence that US land protection efforts by The Nature Conservancy were influenced by broad-scale conservation plans. We suggest five possible causes for our findings. First, administrative rules governing agency land acquisition prioritize land protection within existing local land protection projects over new projects (Wis. Admin. Code NR §1.40). Second, local land protection projects, once approved, are rarely terminated prior to reaching the authorized acreage goal (Wisconsin Department of Natural Resources 2014a*).* Third, degazettement of existing protected areas may improve conservation outcomes (Fuller et al.

2010), albeit with potential negative long-term conservation implications (Mascia and Pailler 2011). However, only recently has the Wisconsin Department of Natural Resources begun this practice, as required by the 2013-2015 state budget bill (Wis. Stat. §23.145). Further, criteria for the sale of existing protected areas are focused on property access issues and whether or not parcels are inside an approved local land protection project boundary, rather than on statewide plans (Wisconsin Department of Natural Resources 2014b). Fourth, there is substantial overlap in plan boundaries over time (>36% overlap with the preceding plan for all plans). The 2008 plan explicitly included priority areas in other plans as a prioritization criterion, and 90% of priority areas in the 2008 plan were partially or entirely encompassed by previous plans. All four factors might decrease the potential influence of recent plans on land protection patterns, particularly since many local land protection projects were initiated by the agency in the 1940s, 1950s, and 1960s. Finally, conservation plans, although intended primarily to guide future actions, may serve in part as reports of past accomplishments for two reasons: 1) agency plans are often expert-based (Lerner et al. 2006) and thus may be biased toward places experts know best (Cowling et al. 2003; Maddock & Samways 2000; Prendergast et al. 1999), and 2) plans may include existing protected areas because they are well known to the public and represent continued priorities for land management (Pohlman et al. 2006).

Do plans influence what kind of land is protected?

After the 2004 and 2008 plans were completed, the agency protected some land cover types (e.g., deciduous forests and wetlands) in greater proportion than indicated in plans and others (e.g., pasture/hay and crop lands) in lesser proportion than indicated in plans. Both trends mirror past efforts (deciduous forests and wetlands comprise 72% of Wisconsin's protected areas, pasture and crop lands only 5%) and may partially reflect a pattern of residual reservation (Pressey 1994)

facilitated by cost, funding, and regulatory considerations and differing conservation strategies. Forested lands are generally cheaper to acquire than agricultural lands in Wisconsin (US Department of Agriculture National Agricultural Statistics Service 2013a, 2013b), and federal Forest Legacy Program funding is specifically for protection of working forests (US Forest Service 2012). Development of wetlands is largely prohibited by state law (Wis. Stat. §281.36), likely increasing availability and lowering costs. In this and other regions, pasture and hay fields are important habitat for grassland-dependent wildlife (Renfrew & Ribic 2008). Cultivated crop lands are important both as a matrix surrounding core grassland habitat and as restoration opportunities for prairies and grasslands (Sample et al. 1997). Restoration is costly (Gardner 2010), however, and local ordinances may discourage or prohibit loss of agricultural lands (Ohm 1999). In addition, grassland conservation and restoration strategies in Wisconsin often focus primarily on providing technical assistance to landowners and facilitating enrollment in federal landowner assistance programs (e.g., US Department of Agriculture Conservation Reserve Program), which do not involve land acquisition by the state agency and thus would not have been captured in our evaluation.

Limitations

Our ability to link plans and subsequent actions was limited in several ways. First, we examined only four conservation plans. While the four plans spanned a long period of time (75 years) and were accompanied by detailed land protection records, they were all developed for a single US state. Second, we had limited post-plan data for the two recent plans, although other plans have been evaluated using similar timeframes (Bottrill et al. 2012; Knight et al. 2008). Third, 1939 and 1964 plan boundaries were only available in coarse paper maps, and the 2004 plan lacked explicit boundaries. Approximating boundaries as circles introduces error (Visconti et al. 2013).

We were conservative in that we chose large circles to capture all potential plan effects, but some circles, particularly in the working landscapes of southern Wisconsin, encompassed non-target land cover types (e.g., crop lands) in addition to targeted habitats. Finally, we considered only natural and institutional outcomes related to land protection as metrics of plan influence. Many other metrics for evaluating plans exist (Bottrill & Pressey 2012). While we did not have comprehensive data to evaluate additional outcomes, we note two examples. First, Wisconsin incorporated the 2008 plan into a state grant program (Wis. Admin. Code NR § 58), subsequently focusing more than $900,000 in federal funding for land management and research within plan boundaries from 2011-2013 (T. Bergeson, *pers. comm.*). Second, agency staff indicated that the 2008 plan helped build support for biodiversity conservation across programs within the agency, and was also used by outside organizations to help lobby for future funding for conservation at the federal level (T. Bergeson, *pers. comm*.).

Conservation implications

Our finding that completion of conservation plans does not coincide with clear and consistent changes in the amount, location, or landcover type of subsequently protected lands at broad scales highlights that conservation decisions are often driven by opportunity, economics, politics, public support, existing policies, and other factors (Bottrill et al. 2012; Knight & Cowling 2007; Knight et al. 2011a, 2011b). We do not suggest that conservation plans are not valuable. Plans provide key justification for protection action when plan priorities and land protection opportunities align (Knight et al. 2011b), and may help facilitate more strategic action during periods when political, economic, and social conditions are favorable (Radeloff et al. 2013). However, we suggest that conservation plans are most likely to be a strong force in guiding land protection actions when dependable, multi-year funding for land protection is present, when

public, institutional, and political support for implementation are strong, and when agencies develop and commit to an implementation strategy. A significant challenge to effective implementation is its protracted nature under most circumstances, requiring strong support and funding over multiple years and sometimes decades (Knight et al. 2011a; Pressey et al. 2013). Public and stakeholder involvement in planning at all stages and scales (e.g., nationwide planning initiatives, statewide conservation and implementation plans, local project plans), including a strong rollout of plans to stakeholders and the public, can foster accountability and help generate and maintain the public, institutional, and political support and funding needed for effective plan implementation (Martin et al. 2012).

Implementation strategies should link broad-scale plans to local land protection initiatives (Pressey et al. 2013), and be actionable within the framework of existing laws, administrative rules and policies governing the agency's land protection actions. Ideally implementation plans include a commitment to monitoring conservation outcomes (Knight et al. 2006), although unfortunately there is little incentive or support for agencies to make such a commitment (Ferraro & Pattanayak 2006). Implementation plans should also identify plan goals which may be difficult to achieve under current laws, administrative rules, and policies, setting the stage for future legal and policy changes needed for more effective long-term implementation.

An important mechanism of plan influence here was the identification of new priority areas in landscapes currently underrepresented in the protected area network. Designating these sites as implementation priorities in the implementation strategy would link broad scale plans more directly to the establishment of new, local land protection projects. The need to link broad-scale and local planning initiatives extends beyond agency settings to conservation organizations as well (e.g., The Nature Conservancy, Bottrill et al. 2012). Linking the two planning scales

through an implementation strategy would help focus staff and stakeholder efforts on building the institutional, political, and public support needed for local projects to succeed. Such implementation strategies were developed for the 2004 plan studied here. Two consecutive five-year implementation plans were approved by the agency oversight board (Wisconsin Department of Natural Resources 2004, 2010). The 2004 implementation plan identified 14 specific land protection projects in which to initiate or concentrate land protection efforts. Two of the seven newly proposed land protection projects were subsequently approved, and land protection occurred in 12 of the 14 priority projects. A decrease in state funding beginning in the late 2000s (Fig. 2f), the large area within the plan boundary (30% of the state), and the influence of other resource-specific plans and funding sources (e.g., the Federal Forest Legacy Program) may have contributed to the lack of clear plan effects observed here.

Explicit identification of plan goals is critical for understanding plan influence. Goals should not be limited to on-the-ground actions, which may be modest. Rather, plan goals should encompass other desired social, institutional, financial, and human outcomes (Bottrill & Pressey 2012; Bottrill et al. 2012). For example, the 2004 plan was developed to assess progress made under Wisconsin's major conservation funding program and to determine if the program should be continued. The plan has since been used to justify continuing the program at stable funding levels, an outcome potentially more important than any specific land protection action.

Up-front assessments of likely plan outcomes, and the spatial scale at which outcomes are likely to occur, can help focus planning processes, plan products, and stakeholder involvement strategies. If on-the-ground actions resulting from plans may be limited, for example if plans are being developed primarily to meet requirements for a modest federal funding program (as was the case with the 2008 plan), then a streamlined process relying on available data and targeting

stakeholders likely to be eligible for funding under the program may be appropriate. If on-the-ground action is most likely to be associated with the establishment of new local land protection projects, then extensive public outreach and involvement where new projects are proposed can generate the local support needed for those projects to succeed (Knight et al. 2008, 2011a). If plan goals and likely impacts involve broadly influencing public or political support for conservation, key public and political leaders should be involved in plan development, and plan products should be tailored and rolled out to these audiences (Pierce et al. 2005).

Finally, while plans should clearly not be driven by opportunity (Margules & Pressey 2000), the practical reality is that land protection often is (Knight & Cowling 2007; Knight et al. 2011b; Pressey 1994). However, many conservation plans, particularly those developed by agencies at the state level, still rely primarily or exclusively on biological data (Lerner et al. 2006). Incorporating into conservation plans the factors (including laws and policies governing land protection actions) potentially constraining conservation action can help identify locations where biological priorities and practical opportunities for action are most likely to intersect (Cowling & Pressey 2003; Knight & Cowling 2007; Knight et al. 2011a; Pressey & Bottrill 2008).

Conclusion

Comprehensive, quantitative evaluations of multiple conservation outcomes across multiple conservation plans are currently lacking in the published literature (Bottrill & Pressey 2012). We have taken a step toward addressing this information gap by quantifying the influence of numerous conservation plans developed by a state land management agency on their subsequent land protection actions. Our approach considered multiple institutional and natural capital metrics of plan influence by quantifying associations between plan completion and changes in the amount, location, and land cover type of protected lands. We considered plan influence at

two spatial scales: comprehensive statewide conservation plans and local land protection projects. We used land protection records that land management agencies and conservation organizations commonly collect as the basis of our evaluation, to facilitate application of this approach to other locations.

We found that comprehensive statewide conservation plans did not have clear or consistent impacts on the amount, location, or landcover type of subsequently protected lands. Our results for Wisconsin are consistent with findings for nationwide land protection efforts in the US by the world's largest land trust (Fisher & Dills 2012), and may reflect the reality of the effectiveness of broad-scale plans in guiding land protection activity in other contexts and locations as well. Our findings suggest that while comprehensive conservation plans do play important roles in conservation, their influence on subsequent land protection efforts may be limited by funding and institutional, political, and public support for implementation, and mediated by laws, administrative rules, and policies governing land protection actions.

In contrast to our findings for statewide plans, we found that the formal approval of local land protection projects was associated with significant activity, much of which occurred almost immediately. In our study area, the project initiation process is strongly linked to agency administrative rules governing land acquisition. Thus we suggest that conservation plans will be most effective when agencies develop and commit to implementation strategies that link broad-scale and local planning initiatives, clearly identifying newly-proposed local land protection projects, and are actionable within the framework of existing laws, administrative rules, and policies governing agency land protection actions. Clearer definition of plan goals and consideration of known influences on plan implementation are also needed to more effectively and efficiently focus conservation planning efforts.

References

Bottrill, M. C., M. Mills, R. L. Pressey, E. T. Game, and C. Groves. 2012. Evaluating Perceived Benefits of Ecoregional Assessments. Conservation Biology **26**:851-861.

Bottrill, M. C., and R. L. Pressey. 2012. The effectiveness and evaluation of conservation planning. Conservation Letters **5**:407.

Bottrill, M.C., Walsh, J.C., Watson, J.E.M., Joseph, L.N., Ortega-Argueta, A., Possingham, H.P., 2011. Does recovery planning improve the status of threatened species? Biological Conservation **144**: 1595-1601

Commission for Environmental Cooperation. 1997. Ecological Regions of North America: Toward a Common Perspective. Communications and Public Outreach Department of the CEC Secretariat, Montreal, Quebec, Canada.

Conservation Biology Institute. 2012. Protected Areas, USA. Corvallis, Oregon. Available from http://consbio.org/products/projects/pad-us-cbi-edition (accessed November 2012).

Cowling, R.M., Pressey, R.L., 2003. Introduction to systematic conservation planning in the Cape Floristic Region. Biological Conservation **112:** 1-13.

Cowling, R. M., R. L. Pressey, R. Sims-Castley, A. le Roux, E. Baard, C. J. Burgers, and G. Palmer. 2003. The expert or the algorithm? - comparison of priority conservation areas in the Cape Floristic Region identified by park managers and reserve selection software. Biological Conservation **112**:147.

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., Cameron, D., Jago, B., Hall, J., Lowe, D., Innes, J., Tanzer, J., Chadwick, V., Thompson, L., Gorman, K., Simmons, M., Barnett, B., Sampson, K., De'ath, G., Mapstone, B., Marsh, H., Possingham, H., Ball, I., Ward, T., Dobbs, K., Aumend, J., Slater, D., Stapleton, K., 2005. Establishing representative no-take areas in the Great Barrier Reef: Large-scale implementation of theory on marine protected areas RID B-1337-2008. Conservation Biology **19**: 1733.

Ferraro, P. J., and S. K. Pattanayak. 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. Plos Biology **4**:482-488.

Fisher, J.R.B., and B. Dills. 2012. Do private conservation activities match science-based conservation priorities? Plos One **7**:e46429.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States. Photogrammetric Engineering and Remote Sensing **77**:858-864.

Fuller, R.A., McDonald-Madden, E., Wilson, K.A., Carwardine, J., Grantham, H.S., Watson, J.E.M., Klein, C.J., Green, D.C., Possingham, H.P., 2010. Replacing underperforming protected areas achieves better conservation outcomes. Nature **466:** 365.

Gardner, H. W. 2010. Tallgrass Prairie Restoration in the Midwestern and Eastern United States. Springer, Dordrecht.

Gleason, M., McCreary, S., Miller-Henson, M., Ugoretz, J., Fox, E., Merrifield, M., McClintock, W., Serpa, P., Hoffman, K., 2010. Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California. Ocean & Coastal Management **53**: 52-68.

Grantham, H.S., Bode, M., McDonald-Madden, E., Game, E.T., Knight, A.T., Possingham, H.P., 2010. Effective conservation planning requires learning and adaptation. Frontiers in Ecology and the Environment **8**: 431-437.

Groves, C. R., D. B. Jensen, L. L. Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson. 2002. Planning for biodiversity conservation: Putting conservation science into practice. Bioscience **52**:499.

Joppa, L.N., Pfaff, A., 2009. High and Far: Biases in the Location of Protected Areas. Plos One **4**: e8273.

Knight, A. T., and R. M. Cowling. 2007. Embracing opportunism in the selection of priority conservation areas. Conservation Biology **21**:1124.

Knight, A. T., R. M. Cowling, A. F. Boshoff, S. L. Wilson, and S. M. Pierce. 2011a. Walking in STEP: Lessons for linking spatial prioritisations to implementation strategies. Biological Conservation **144**:202-211.

Knight, A.T., Cowling, R.M., Campbell, B.M., 2006. An operational model for implementing conservation action. Conservation Biology **20**: 408-419.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell. 2008. Knowing but not doing: Selecting priority conservation areas and the research-implementation gap. Conservation Biology **22**:610.

Knight, A. T., H. S. Grantham, R. J. Smith, G. K. McGregor, H. P. Possingham, and R. M. Cowling. 2011b. Land managers' willingness-to-sell defines conservation opportunity for protected area expansion. Biological Conservation **144**:2623-2630.

Lerner, J., B. Cochran, and J. Michalak. 2006. Conservation Across the Landscape: A Review of the State Wildlife Action Plans. Defenders of Wildlife, Washington D.C.

Maddock, A. H., and M. J. Samways. 2000. Planning for biodiversity conservation based on the knowledge of biologists. Biodiversity and Conservation **9**:1153.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature **405**:243.

Martin, T.G., Nally, S., Burbidge, A.A., Arnall, S., Garnett, S.T., Hayward, M.W., Lumsden, L.F., Menkhorst, P., McDonald-Madden, E., Possingham, H.P., 2012. Acting fast helps avoid extinction. Conservation Letters **5**: 274-280.

Mascia, M.B., Pailler, S., 2011. Protected area downgrading, downsizing, and degazettement (PADDD) and its conservation implications. Conservation Letters **4**: 9-20.

National Conservation Easement Database. 2013. West Linn, Oregon. Available from http://www.conservationeasement.us (accessed July 2013).

National Park Service. 1964. Parks for America: A survey of park and related resources in the fifty states, and a preliminary plan. US Department of the Interior, Washington, D.C.

Ohm, B. W. 1999. Guide to community planning in Wisconsin. Department of Urban and Regional Planning, University of Wisconsin-Madison/Extension, Madison, WI.

Pierce, S. M., R. M. Cowling, A. T. Knight, A. T. Lombard, M. Rouget, and T. Wolf. 2005. Systematic conservation planning products for land-use planning: Interpretation for implementation. Biological Conservation **125**:441.

Pohlman, J. D., G. A. Bartelt, A. C. Hanson, III, P. H. Scott, and C. D. Thompson, editors. 2006. Wisconsin Land Legacy Report: An inventory of places to meet Wisconsin's future conservation and recreation needs. Wisconsin Department of Natural Resources, Madison, WI.

Prendergast, J. R., R. M. Quinn, and J. H. Lawton. 1999. The gaps between theory and practice in selecting nature reserves. Conservation Biology **13**:484.

Pressey, R. L. 1994. Ad Hoc Reservations - Forward or backward steps in developing representative reserve systems. Conservation Biology **8**:662.

Pressey, R. L., and M. C. Bottrill. 2008. Opportunism, threats, and the evolution of systematic conservation planning. Conservation Biology **22**.

Pressey, R. L., C. J. Humphries, C. R. Margules, R. I. Vanewright, and P. H. Williams. 1993. Beyond opportunism - key principles for systematic reserve selection. Trends in Ecology and Evolution **8**:124.

Pressey, R.L., Mills, M., Weeks, R., Day, J.C., 2013. The plan of the day: Managing the dynamic transition from regional conservation designs to local conservation actions. Biological Conservation **166**: 155-169.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Radeloff, V. C., F. Beaudry, T. M. Brooks, V. Butsic, M. Dubinin, T. Kuemmerle, and A. M. Pidgeon. 2013. Hot moments for biodiversity conservation. Conservation Letters **6**:58-65.

Radeloff, V. C., R. B. Hammer, and S. I. Stewart. 2005. Rural and suburban sprawl in the US Midwest from 1940 to 2000 and its relation to forest fragmentation. Conservation Biology **19**:793.

Renfrew, R.B., Ribic, C.A., 2008. Multi-scale models of grassland passerine abundance in a fragmented system in Wisconsin. Landscape Ecology **23**: 181-193.

Rhemtulla, J. M., D. J. Mladenoff, and M. K. Clayton. 2007. Regional land-cover conversion in the US upper Midwest: magnitude of change and limited recovery (1850-1935-1993). Landscape Ecology **22**:57.

Rodgers, W. H. J. 1993-1994. Seven statutory wonders of US environmental law: Origins and morphology. Loyola of Los Angeles Law Review **27**:1009-1021.

Sample, D.W., Mossman, M.J., Wisconsin. Bureau of Integrated Science Services., 1997. Managing habitat for grassland birds : a guide for Wisconsin. Wisconsin Department of Natural Resources, Bureau of Integrated Science Services, Madison, WI.

Scott, J.M., Davis, F.W., McGhie, R.G., Wright, R.G., Groves, C., Estes, J., 2001. Nature reserves: Do they capture the full range of America's biological diversity? RID B-7010-2009. Ecological Applications **11**: 999.

Theobald, H.R., and P.V. Robbins, editors. 1970. The state of Wisconsin blue book 1970. Wisconsin Legislative Reference Bureau, Madison, Wisconsin.

Theobald, H.R., and P.V. Robbins, editors. 1973. The state of Wisconsin blue book 1973. Wisconsin Legislative Reference Bureau, Madison, Wisconsin.

Theobald, H.R., and P.V. Robbins, editors. 1977. The state of Wisconsin 1977 blue book. Wisconsin Legislative Reference Bureau, Madison, Wisconsin.

Theobald, H.R., and P.V. Robbins, editors. 1985. The state of Wisconsin 1985-1986 blue book. Wisconsin Legislative Reference Bureau, Madison, Wisconsin.

US Bureau of Economic Analysis. 2013a. National gross domestic product, 1929-2012. Available from http://www.bea.gov/national/index.htm (accessed June 2013).

US Bureau of Economic Analysis. 2013b. Wisconsin gross domestic product, 1963-2012. Available from http://www.bea.gov/iTable/index_regional.cfm (accessed June 2013).

US Bureau of Labor Statistics. 2013. Consumer price index-urban wage earners and clerical workers, 1913-2013. Available from http://www.bls.gov/cpi (accessed July 2013).

US Bureau of the Census. 1975. Historical statistics of the United States, colonial times to 1970, bicentennial edition. US Department of Commerce, Washington D.C.

US Department of Agriculture National Agricultural Statistics Service, 2013a. Wisconsin forest land sales– 2012. Madison, Wisconsin.

US Department of Agriculture National Agricultural Statistics Service. 2013b. Wisconsin total agricultural land sales – 2012, Madison, Wisconsin.

US Department of the Interior. 2010. Fiscal year 2011: The Interior budget in brief, appendix F: Land and Water Conservation Fund. Washington, D.C.

US Department of the Interior. 2011. Fiscal year 2012: The Interior budget in brief, appendix F: Land and Water Conservation Fund. Washington, D.C.

US Department of the Interior. 2012. Fiscal year 2013: The Interior budget in brief, appendix E: Land and Water Conservation Fund. Washington, D.C.

US Fish and Wildlife Service. 2006. Guidelines for the State Wildlife Grant program. Available from http://teaming.com/sites/default/files/SWG%20Guidelines.pdf (accessed November 2013).

US Fish and Wildlife Service. 2014. National Wildlife Refuge System Draft Strategic Growth Policy. Available from http://www.fws.gov/refuges/planning/StrategicGrowth.html (accessed May 2014).

US Forest Service. 2012. Forest legacy program. Available from http://www.fs.fed.us/spf/coop/programs/loa/aboutflp.shtml (accessed October 2013)

Vincent, C.H. 2010. Land and Water Conservation Fund: Overview, funding history, and issues. Congressional Research Service, Washington D.C.

Voigt, L.P. 1962. ORAP [Outdoor Recreation Areas Program] gets underway. Wisconsin Conservation Bulletin **27(3):**3-6.

Wisconsin Department of Natural Resources. 2003. Manual Code 2105.2: Feasibility study and Wisconsin Environmental Policy Act analysis for establishing or modifying project boundaries. Madison, WI.

Wisconsin Department of Natural Resources. 2004. Implementation Strategy for the Wisconsin Land Legacy Report. Madison, WI.

Wisconsin Department of Natural Resources. 2005. Wisconsin's Strategy for Wildlife Species of Greatest Conservation Need, A State Wildlife Action Plan. Madison, WI.

Wisconsin Department of Natural Resources. 2008. Wisconsin's Wildlife Action Plan (2005-2015) Implementation: Priority Conservation Actions and Conservation Opportunity Areas. Madison, WI.

Wisconsin Department of Natural Resources. 2010. The DNR Land Acquisition Strategy for the Stewardship Program, with action items for 2010 to 2015. Madison, WI.

Wisconsin Department of Natural Resources. 2012. Wisconsin’s Forest Legacy Areas. Available from http://dnr.wi.gov/topic/ForestPlanning/legacyAreas.html (accessed May 2014).

Wisconsin Department of Natural Resources. 2013a. Managed lands database. Available from ftp://ftp.wi.gov/DNR/public/Lands (accessed May 2013).

Wisconsin Department of Natural Resources. 2013b. Feasibility Studies. Available from http://dnr.wi.gov/topic/lands/masterplanning/Feasibility.html (accessed November 2013).

Wisconsin Department of Natural Resources. 2013c. 2013-2014 DNR Action Plan. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Wisconsin Department of Natural Resources. 2014a. Wisconsin Department of Natural Resources land records database. Available from Bureau of Facilities and Lands, Wisconsin Department of Natural Resources, 101 S. Webster St., Madison, WI, 53707.

Wisconsin Department of Natural Resources. 2014b. Real Estate Program land sales. Available from http://dnr.wi.gov/topic/lands/RealEstate/landsale.html (accessed May 2014).

Wisconsin Legislative Reference Bureau, 2011. State of Wisconsin 2011-2012 blue book. Wisconsin Department of Administration, Madison, Wisconsin.

Wisconsin State Planning Board and Conservation Commission. 1939. A Park, Parkway and Recreational Area Plan. Madison, WI.

Table 1. Descriptions of each comprehensive statewide conservation plan examined, including the year completed, plan goal, plan impetus, primary planning agency, number of priority areas, and total area included within plan boundary (km^2). Please see Appendix B for additional information on each plan.

Year completed	Plan goal	Plan impetus	Primary planning agency	Number of priority areas in plan	Total area inside plan boundary (percent of state)	Source
1939	Provide an adequate and flexible system for the protection, development and use of forests, fish and game, lakes, streams, plant life, flowers, and other outdoor resources in the State of Wisconsin.	Legislative mandate by the state to develop a recreational plan for the state and 'designate the lands most appropriate for state parks, which with a system of valley	Wisconsin Conservation Commission (now the Wisconsin Department of Natural	155	17,121 km^2 (11.8%)	Wisconsin State Planning Board and Conservation Commission 1939

		parkways, will comprise a complete plan of recreational and educational areas, thus incorporating and conserving our most picturesque and historical natural landscapes.'	Resources)			
1964	Identify and protect irreplaceable scenic, scientific, and historic resources for future generations	Nationwide park planning effort stemming from 'an unprecedented surge of interest and concern across the country in meeting the outdoor	National Park Service, in cooperation with federal, state and local parks and land management	204	30,842 km^2 (21.2%)	National Park Service 1964

		recreation needs of the Nation.'	agencies			
2004	Identify the most important places to meet Wisconsin's conservation and recreation needs over the next 50 years	Recommendation by a panel convened by the state's governor to assess progress made under Wisconsin's major conservation funding program and determine if the program should be continued	Wisconsin Department of Natural Resources	230	44,228 km^2 (30.4%)	Pohlman et al. 2006
2008	The federally-mandated goal for all state Wildlife Action Plans nationwide was to address the needs of declining wildlife	Plan completion was required by the federal government if states wished to be eligible	Wisconsin Department of Natural	255	37,033 km^2 (25.5%)	Wisconsin Department of Natural Resources

	species before they reach the point of possible listing as endangered or threatened. Wisconsin's Wildlife Action Plan 'stresses the importance of protecting habitat as a means of protecting whole suites of species rather than focusing conservation efforts on individual species.'	for funding from the State and Tribal Wildlife Grants Program	Resources	2005, 2008

Table 2. Land cover composition of all lands inside boundaries of the two recent plans, unprotected lands only within each plan boundary, all lands protected in the years since completion of each plan, the entire existing statewide network of protected lands, and all currently unprotected lands in the state. The composition of all lands within plan boundaries represents the best estimate of overall land cover protection goals for each plan. The composition of unprotected lands with the boundary of each plan represents the best estimate of the desired composition of lands remaining to be protected. The final two columns describe the composition of the current protected areas network in the state and the composition of lands that may be available for future land protection. Units are square kilometers; percentages are of the total in each column.

	2004 plan			**2008 plan**				
	All lands within plan boundary	Unprotected lands only within plan boundary	Lands protected since 2004	All lands within plan boundary	Unprotected lands only within plan boundary	Lands protected since 2008	All currently protected lands in Wisconsin	All currently unprotected lands in Wisconsin
Deciduous	12,690	7,557	454	13,453	7,528	203	12,053	31,639

	(28.7%)	(24.1%)	(43.9%)	(36.3%)	(33.3%)	(45.4%)	(43.4%)	(26.9%)
Evergreen	1,156	551	20	1,342	477	11	1,383	1,954
	(2.6%)	(1.8%)	(1.9%)	(3.6%)	(2.1%)	(2.4%)	(5.0%)	(1.7%)
Mixed	1,808	932	66	1,701	634	24	2,099	3,128
	(4.1%)	(3.0%)	(6.4%)	(4.6%)	(2.8%)	(5.3%)	(7.6%)	(2.7%)
Shrub, grassland, and herbaceous	1,201	682	29	1,364	658	14	1,119	2,666
	(2.7%)	(2.2%)	(2.8%)	(3.7%)	(2.9%)	(3.2%)	(4.0%)	(2.3%)
Pasture/hay	3,726	3,626	19	2,357	2,278	10	244	15,324
	(8.4%)	(11.5%)	(1.8%)	(6.4%)	(10.1%)	(2.3%)	(0.9%)	(13.0%)
Cultivated crops	8,793	8,354	82	5,576	5,174	35	1,026	37,172
	(19.9%)	(26.6%)	(7.9%)	(15.1%)	(22.9%)	(7.8%)	(3.7%)	(31.6%)

Wetlands	8,465	4,511	293	7,519	3,298	128	7,898	12,012
	(19.1%)	(14.4%)	(28.3%)	(20.3%)	(14.6%)	(28.6%)	(28.4%)	(10.2%)
Barren	31	25	0	24	18	0	9	88
	(0.1%)	(0.1%)		(0.1%)	(0.1%)		(0.0%)	(0.1%)
Green space	1,725	1,395	22	1,324	946	11	700	5,294
	(3.9%)	(4.4%)	(2.1%)	(3.6%)	(4.2%)	(2.4%)	(2.5%)	(4.5%)
Developed	1,389	1,344	2	504	462	1	101	4,334
	(3.1%)	(4.3%)	(0.2%)	(1.4%)	(2.0%)	(0.2%)	(0.4%)	(3.7%)
Open water	3,261	2,442	47	1,884	1,155	10	1,150	3,928
	(7.4%)	(7.8%)	(4.6%)	(5.1%)	(5.1%)	(2.2%)	(4.1%)	(3.3%)
Total	44,244	31,420	1,033	37,048	22,629	448	27,781	117,538

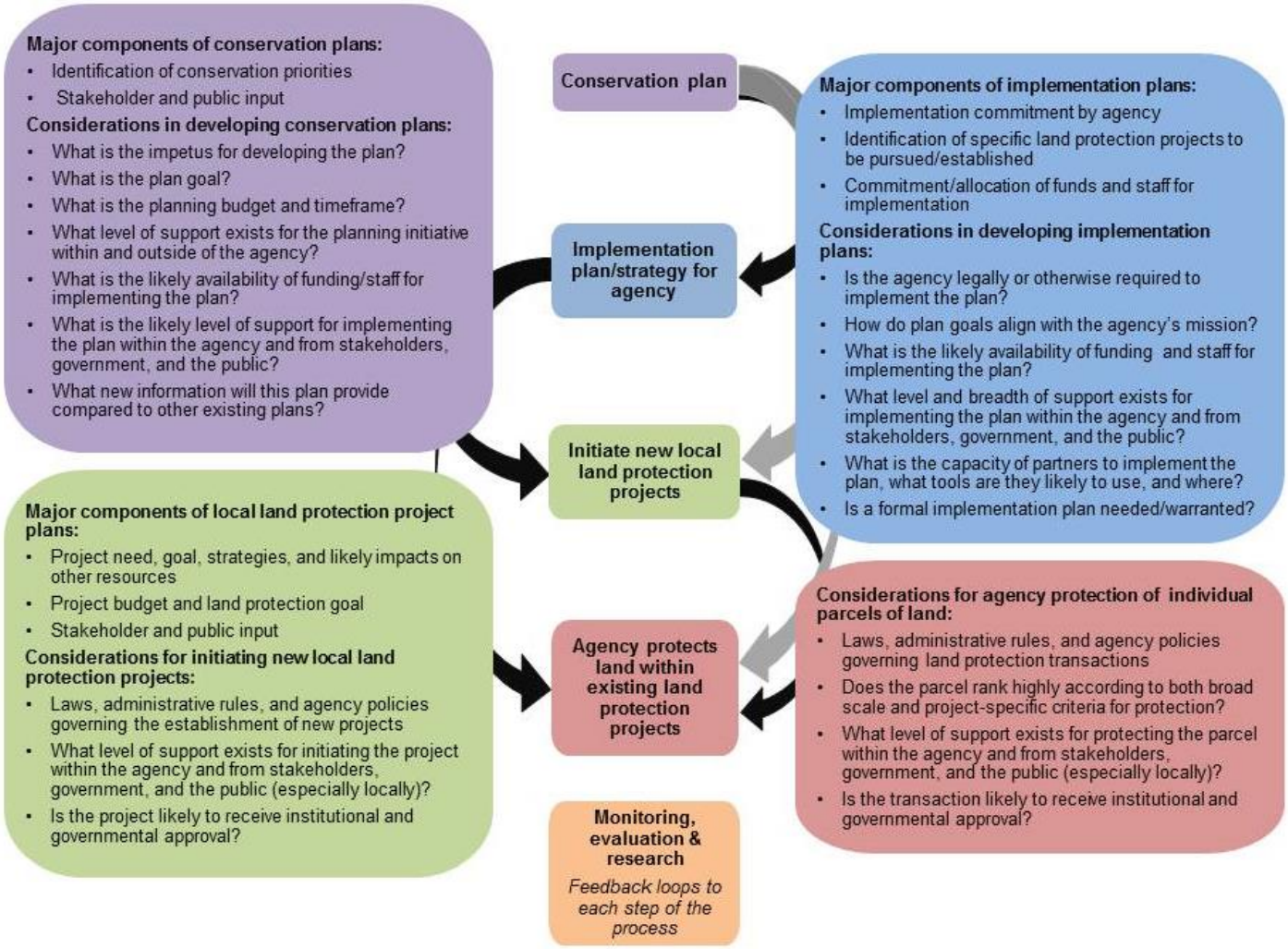

Figure 1. Major steps and pathways by which land management agencies may implement conservation plans through land protection actions. Major components and considerations for each step of the process are color coded to match the corresponding step. Ideal/major pathways for action are indicated with black arrows; alternate pathways for action are indicated with grey arrows.

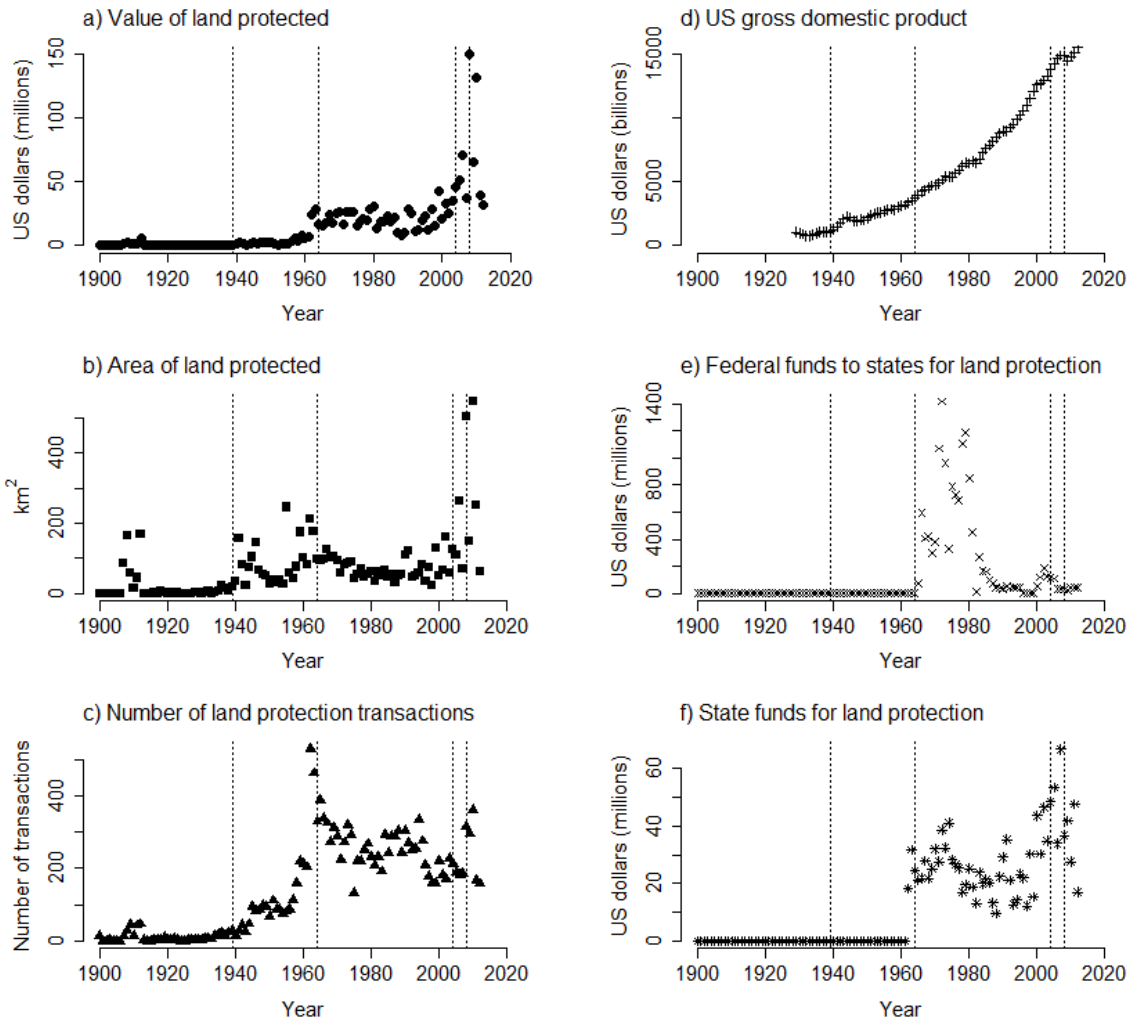

Figure 2. Total annual statewide a) value of land protected, b) area of land protected, and c) number of land protection transactions; and d) US gross domestic product, e) federal funding granted to states for land protection, and f) state funds for land protection, and f) state funds for land protection for each year between 1900 and 2012. Dotted lines indicate years in which conservation plans were completed.

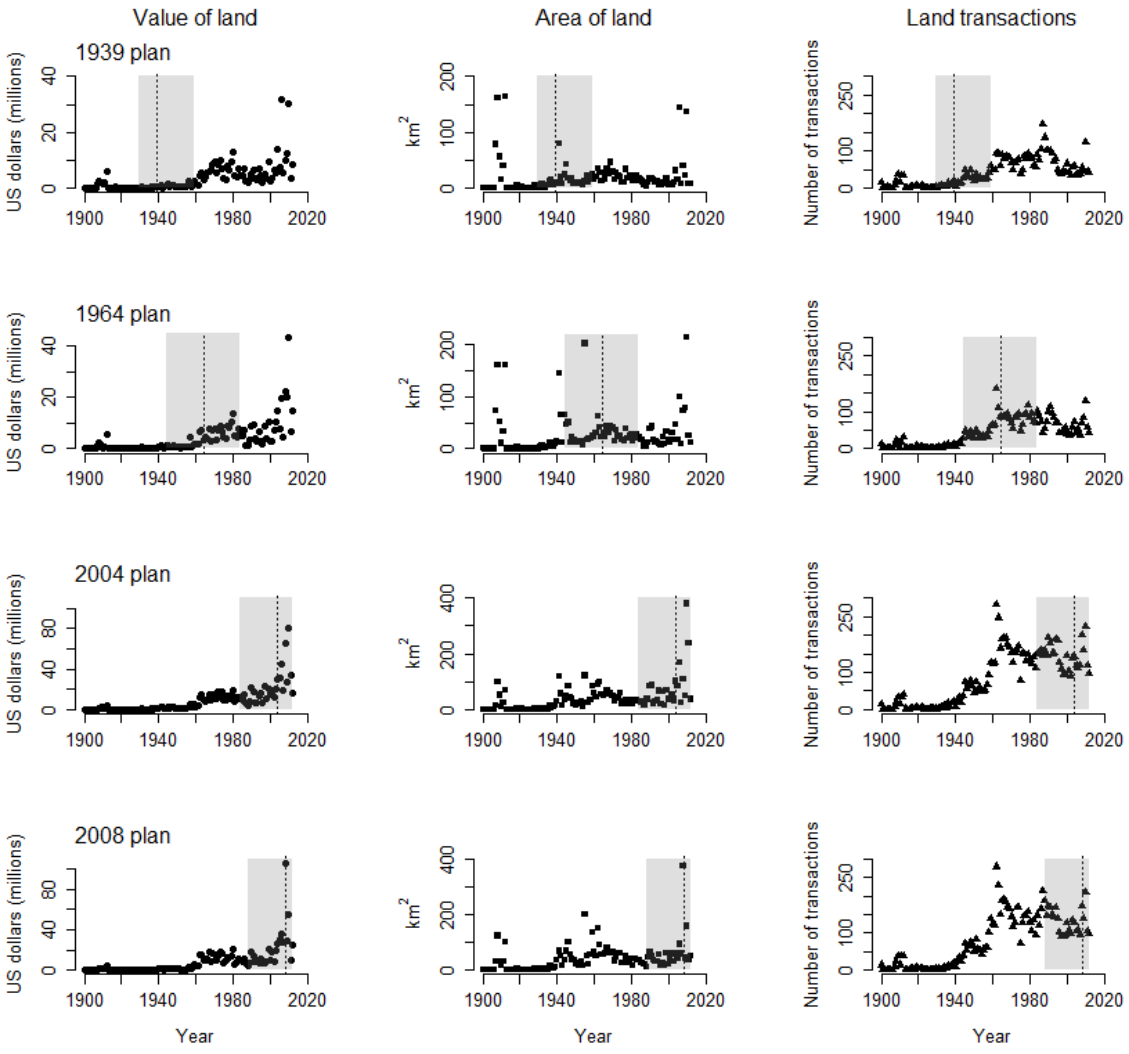

Figure 3. Total annual value of land protected (left column), area of land protected (middle column), and number of land protection transactions (right column) within plan boundaries only for each plan between 1900 and 2012. Dotted lines indicate the year in which each plan was completed. Grey shading indicates years analyzed statistically. Note that the scale of the y axis for the 2004 and 2008 plans differs from that of the 1939 and 1964 plans for value and area of land protected.

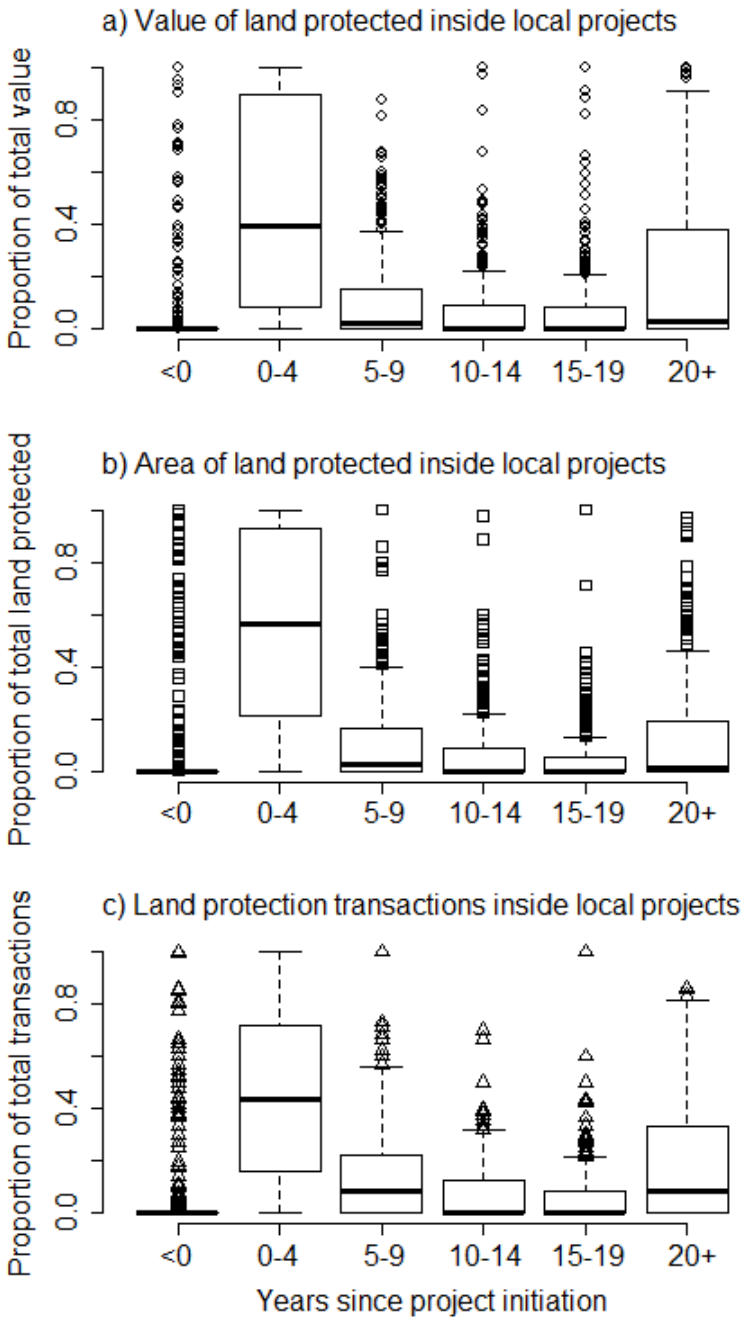

Figure 4. Temporal distribution of land protection activity inside individual projects (n=371 projects). We present three metrics of land protection activity: a) value of land protected, b) area of land protected, and c) number of land protection transactions. Each project is represented once in each bin, corresponding to the proportion of all land protection activity on that project which

occurred during that time period. Note that the first and last bins include a time period of more than 5 years.

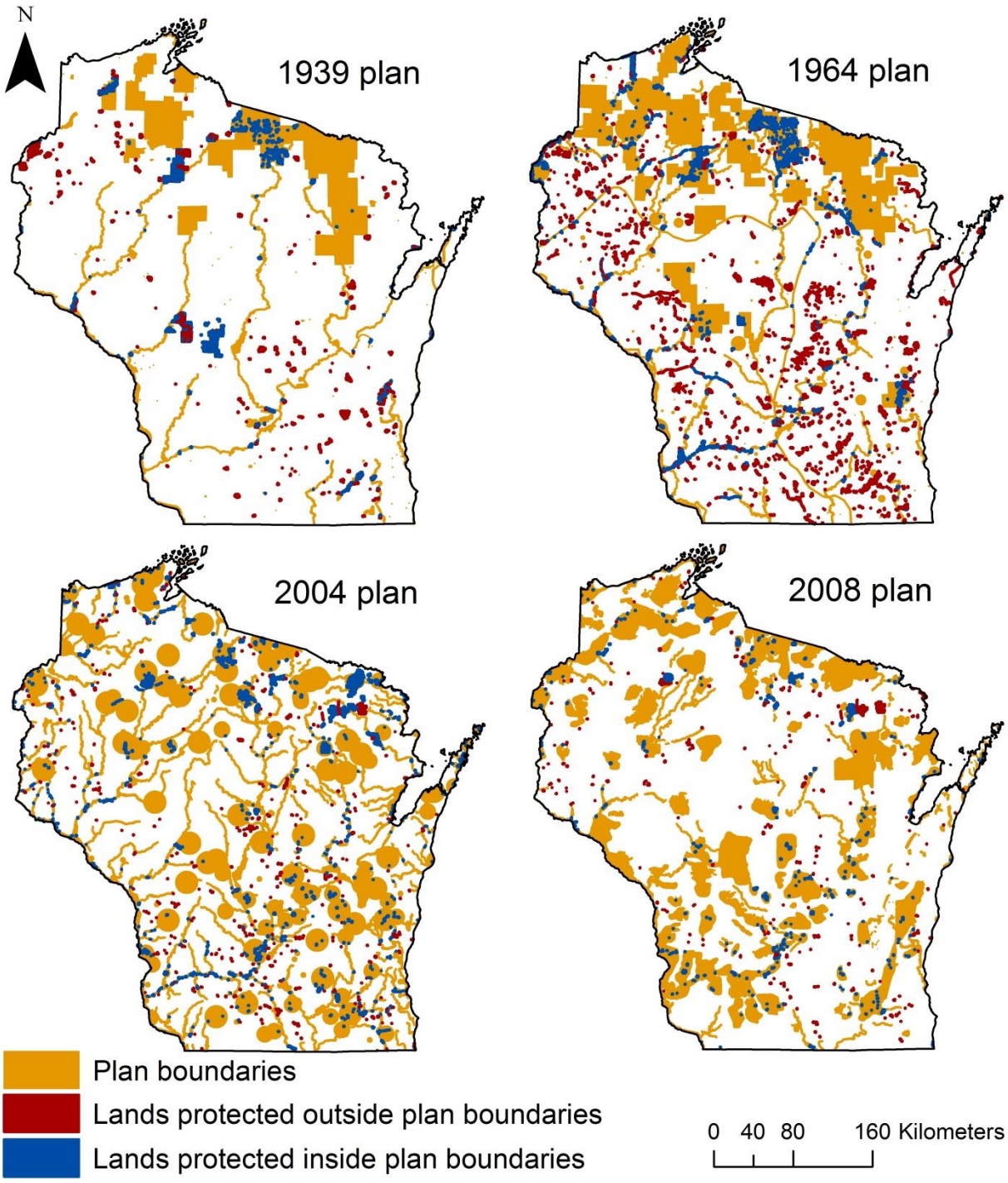

Figure 5. Plan boundaries and the location of lands protected inside and outside of plan boundaries within twenty years after plan completion for each plan. The size of small protected areas has been exaggerated slightly to more clearly show their spatial distribution.

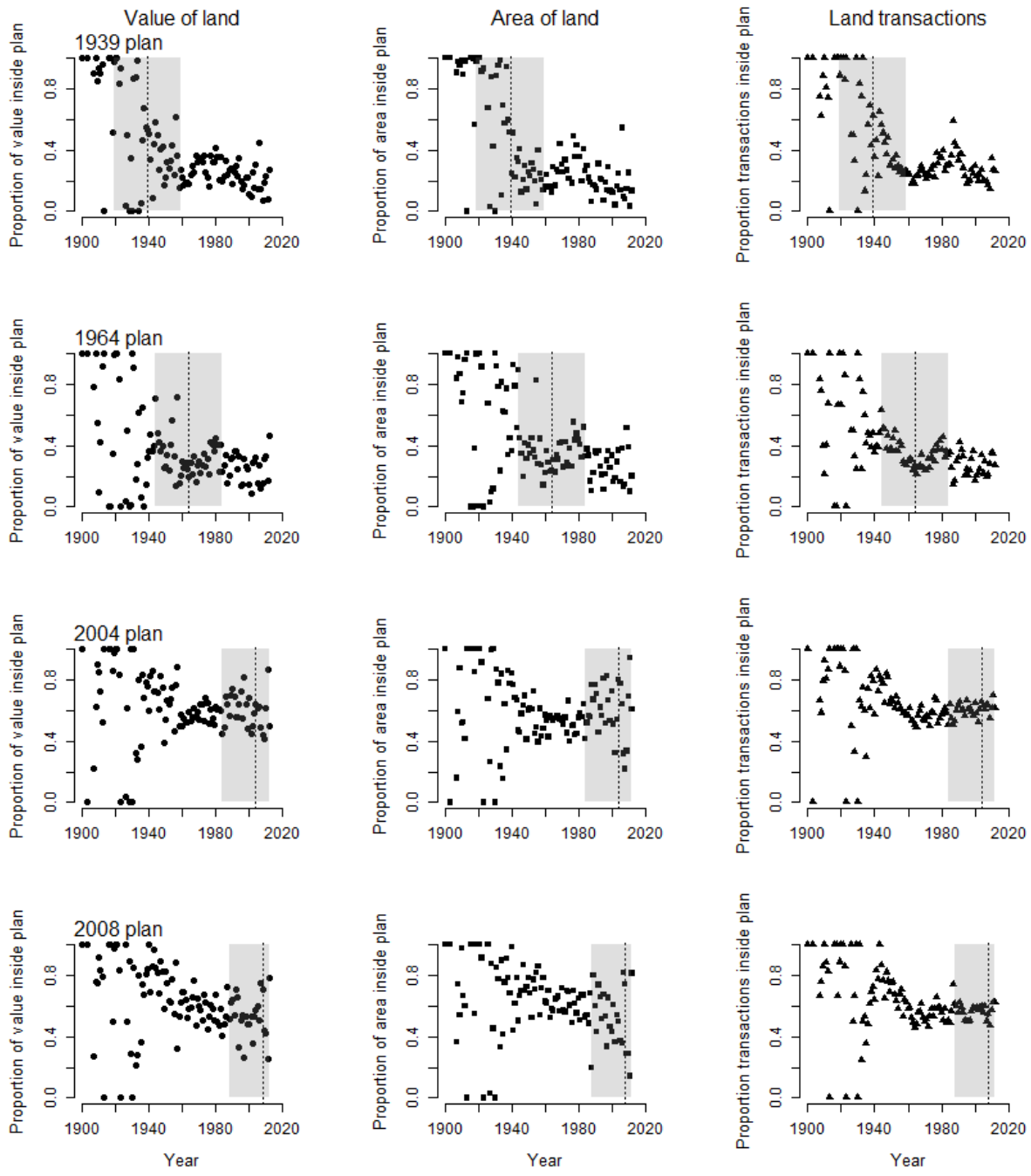

Figure 6. Spatial focusing of land protection activity within plan boundaries for each of four plans (completed in 1939, 1964, 2004, and 2008) before and after plan completion. We present three metrics of land protection activity for each plan: the proportion of the total statewide value of land protected (left column), area of land protected (middle column), and number of land protection transactions (right column) that occurred within plan boundaries in each year for each

plan. Dotted lines indicate the year in which each plan was completed. Grey shading indicates years analyzed statistically.

Chapter 2: Improving the utility of existing conservation plans using projected housing development

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.

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 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 to10 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 their

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.

Methods

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 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 et al., 2005).

Data

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 (500-5,000 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).

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 publically-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.

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).

Analyses

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., 2014).

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 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 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 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., 2014).

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.

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 3). 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.

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 author's 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.

Results

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 sites in both plans located primarily in northern Wisconsin (Fig. 7). Less than a quarter of priority areas were highly threatened by current or projected future housing density (17-18% and 21-24%, respectively, Fig. 8). Most highly threatened priority areas occurred in more urbanized eastern Wisconsin or in northwestern Wisconsin, within commuting distance of Minneapolis, Minnesota (Fig. 8). 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. 8).

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. 7) 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. 8). The percentage of priority areas under medium or high threat from rapid housing growth was similar for both plans (Fig. 8).

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.

Targeting, scheduling, and tailoring conservation actions

Conservation strongholds occurred primarily in northern Wisconsin in both plans (Fig. 9), 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 4). The critical consideration for *conservation strongholds* is whether conservation goals have been achieved given the high level of existing protection (Table 5). 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 5).

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 4). Many sites in this category were located in the more developed eastern half of Wisconsin (Fig. 9). 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 5). Where original conservation goals are no longer attainable, alternative goals for or divestment of existing properties should be considered (Table 5).

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. 9). 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 5). 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 5).

An additional 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. 9). 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 5). It may be possible to achieve many conservation objectives in working landscapes using strategies that maintain lands in private ownership (Table 5).

Discussion

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.

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 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.

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.

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 5).

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 can't 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 *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 5).

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 of 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.

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).

Conclusion

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 requiring 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.

References

Acquisition of Recreational Land. (1985).Wisconsin Administrative Code NR 1.40. Retrieved September 20, 2013 from https://docs.legis.wisconsin.gov/code/admin_code/nr/001/1.pdf

Ando, A., Camm, J., Polasky, S., & Solow, A. (1998). Species distributions, land values, and efficient conservation. *Science, 279*(5359) doi:10.1126/science.279.5359.2126

Armsworth, P. R., Daily, G. C., Kareiva, P., & Sanchirico, J. N. (2006). Land market feedbacks can undermine biodiversity conservation. *Proceedings of the National Academy of Sciences of the United States of America, 103*(14), 5403-5408. doi:10.1073/pnas.0505278103

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C. N., Game, E. T., & Possingham, H. P. (2009). Finite conservation funds mean triage is unavoidable. *Trends in Ecology & Evolution, 24*(4), 183-184. doi:10.1016/j.tree.2008.11.007

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C. N., Game, E. T., & Possingham, H. P. (2008). Is conservation triage just smart decision making? *Trends in Ecology & Evolution, 23*(12), 649-654. doi:10.1016/j.tree.2008.07.007

Bottrill, M. C., Mills, M., Pressey, R. L., Game, E. T., & Groves, C. (2012). Evaluating perceived benefits of ecoregional assessments. *Conservation Biology, 26*(5), 851-861. doi: 10.1111/j.1523-1739.2012.01898.x

Bottrill, M. C., & Pressey, R. L. (2012). The effectiveness and evaluation of conservation planning. *Conservation Letters, 5*(6), 407. doi: 10.1111/j.1755-263X.2012.00268.x

Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A. B., Gerlach, J., Hoffmann, M., Lamoreux, J. F., & Rodrigues, A. S. L. (2006). Global biodiversity conservation priorities. *Science, 313*(5783), 58-61. doi:10.1126/science.1127609

Brown, D. G., Johnson, K. M., Loveland, T. R., & Theobald, D. M. (2005). Rural land-use trends in the conterminous United States, 1950-2000. *Ecological Applications, 15*(6), 1851-1863. doi:10.1890/03-5220

Capozza, D. R., & Helsley, R. W. (1989). The fundamentals of land prices and urban-growth. *Journal of Urban Economics, 26*(3), 295-306. doi: 10.1016/0094-1190(89)90003-x

Chown, S. L., Rodrigues, A. S. L., Gremmen, N. J. M., & Gaston, K. (2001). World heritage status and conservation of southern ocean islands. *Conservation Biology, 15*(3), 550-557. doi:10.1046/j.1523-1739.2001.015003550.x

Conservation Biology Institute. (2012). Protected Areas, USA. Corvallis, Oregon. Retrieved November 1, 2012 from http://consbio.org/products/projects/pad-us-cbi-edition

Cowling, R., Pressey, R., Sims-Castley, R., le Roux, A., Baard, E., Burgers, C., & Palmer, G. (2003). The expert or the algorithm? - comparison of priority conservation areas in the Cape Floristic Region identified by park managers and reserve selection software. *Biological Conservation, 112*(1-2), 147-167. doi:10.1016/S0006-3207(02)00397-X

Curtis, J. T. (1971). *The vegetation of Wisconsin; an ordination of plant communities*. Madison, Wisconsin: University of Wisconsin Press.

Endangered Resources Grant Programs. (2008). Wisconsin Administrative Code NR 58. Retrieved September 20, 2013 from https://docs.legis.wisconsin.gov/code/admin_code/nr/001/58.pdf

Fuller, R. A., McDonald-Madden, E., Wilson, K. A., Carwardine, J., Grantham, H. S., Watson, J. E. M., & Possingham, H. P. (2010). Replacing underperforming protected areas achieves better conservation outcomes. *Nature, 466*(7304), 365-367. doi:10.1038/nature09180

Groves, C. R., Jensen, D. B., Valutis, L. L., Redford, K. H., Shaffer, M. L., Scott, J. M., Baumgartner, J. V., Higgins, J. V., Beck, M.W., & Anderson, M. G. (2002). Planning for biodiversity conservation: Putting conservation science into practice. *Bioscience, 52*(6), 499. doi: 10.1641/0006-3568(2002)052[0499:pfbcpc]2.0.co;2

Hamilton, C. M., Martinuzzi, S., Plantinga, A. J., Radeloff, V. C., Lewis, D. J., Thogmartin, W. E., Heglund, P.J., & Pidgeon, A. M. (2013). Current and future land use around a nationwide protected area network. *Plos One, 8*(1), e55737. doi: 10.1371/journal.pone.0055737

Hammer, R. B., Stewart, S. I., Hawbaker, T. J., & Radeloff, V. C. (2009). Housing growth, forests, and public lands in northern Wisconsin from 1940 to 2000. *Journal of Environmental Management, 90*(8), 2690-2698. doi:10.1016/j.jenvman.2009.02.012

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., & Jones, A. (2005). Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. *Ecological Applications, 15*(6), 1893-1905. doi:10.1890/05-5221

Joppa, L. N., & Pfaff, A. (2009). High and far: Biases in the location of protected areas. *Plos One, 4*(12), e8273. doi:10.1371/journal.pone.0008273

Knight, A. T., & Cowling, R. M. (2007). Embracing opportunism in the selection of priority conservation areas. *Conservation Biology,* 21, 1124-1126. doi: 10.1111/j.1523-1739.2007.00690.x

Knight, A. T., Cowling, R. M., Rouget, M., Balmford, A., Lombard, A. T., & Campbell, B. M. (2008). Knowing but not doing: Selecting priority conservation areas and the research-implementation gap. *Conservation Biology, 22*(3), 610-617. doi:10.1111/j.1523-1739.2008.00914.x

Knight, A. T., Grantham, H. S., Smith, R. J., McGregor, G. K., Possingham, H. P., & Cowling, R. M.. 2011. Land managers' willingness-to-sell defines conservation opportunity for

protected area expansion. *Biological Conservation*, 144, 2623-2630. doi: 10.1016/j.biocon.2011.07.013

Lepczyk, C. A., Flather, C. H., Radeloff, V. C., Pidgeon, A. M., Hammer, R. B., & Liu, J. (2008). Human impacts on regional avian diversity and abundance. *Conservation Biology, 22*(2), 405-416. doi: 10.1111/j.1523-1739.2008.00881.x

Lerner, J., Cochran, B., & Michalak, J. (2006). *Conservation across the landscape: A review of the State Wildlife Action Plans*. Washington D.C.: Defenders of Wildlife.

Maddock, A. H., & Samways, M. J. (2000). Planning for biodiversity conservation based on the knowledge of biologists. *Biodiversity and Conservation, 9*(8), 1153-1169. doi:10.1023/A:1008992602151

Maguire, L. A., & Albright, E. A. (2005). Can behavioral decision theory explain risk-averse fire management decisions? *Forest Ecology and Management, 211*(1-2), 47-58. doi:10.1016/j.foreco.2005.01.027

Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. *Nature, 405*(6783), 243-253. doi:10.1038/35012251

Marone, M., Rhodes, J.R., & Gibbons, P. (2013). Calculating the benefit of conservation actions. *Conservation Letters, 6*(5), 359-367. doi:10.1111/conl.12007

McBride, M. F., Wilson, K. A., Bode, M., & Possingham, H. P. (2007). Incorporating the effects of socioeconomic uncertainty into priority setting for conservation investment. *Conservation Biology, 21*(6), 1463-1474. doi:10.1111/j.1523-1739.2007.00832.x

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation. *Bioscience, 52*(10), 883-890. doi:10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2

Meynard, C. N., Howell, C. A., & Quinn, J. F. (2009). Comparing alternative systematic conservation planning strategies against a politically driven conservation plan. *Biodiversity and Conservation, 18*(12), 3061-3083. doi:10.1007/s10531-009-9625-3

Moilanen, A., Wilson, K. A., & Possingham, H. P. (2009). *Spatial conservation prioritization: Quantitative methods and computational tools*. Oxford, New York: Oxford University Press.

Myers, N., Mittermeier, R., Mittermeier, C., da Fonseca, G., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*(6772), 853-858. doi:10.1038/35002501

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H., & Rouget, M. (2006). Integrating economic costs into conservation planning. *Trends in Ecology & Evolution, 21*(12), 681-687. doi:10.1016/j.tree.2006.10.003

National Conservation Easement Database. (2012). West Linn, Oregon. Retrieved October 31, 2012 from http://www.conservationeasement.us

Newburn, D., Reed, S., Berck, P., & Merenlender, A. (2005). Economics and land-use change in prioritizing private land conservation. *Conservation Biology, 19*(5), 1411-1420. doi:10.1111/j.1523-1739.2005.00199.x

Newburn, D. A., Berck, P., & Merenlender, A. M. (2006). Habitat and open space at risk of land-use conversion: Targeting strategies for land conservation. *American Journal of Agricultural Economics, 88*(1), 28-42. doi:10.1111/j.1467-8276.2006.00837.x

Noss, R. F., Carroll, C., Vance-Borland, K., & Wuerthner, G. (2002). A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. *Conservation Biology, 16*(4), 895-908. doi: 10.1046/j.1523-1739.2002.01405.x

O'Connor, C., Marvier, M., & Kareiva, P. (2003). Biological vs. social, economic and political priority-setting in conservation. *Ecology Letters, 6*(8), 706-711. doi:10.1046/j.1461-0248.2003.00499.x

Pohlman, J. D., Bartelt, G. A., Hanson, A. C., III, Scott, P. H., & Thompson, C. D. (Eds.). (2006). *Wisconsin land legacy report: An inventory of places to meet Wisconsin's future conservation and recreation needs*. Madison, Wisconsin: Wisconsin Department of Natural Resources.

Polasky, S., Nelson, E., Lonsdorf, E., Fackler, P., & Starfield, A. (2005). Conserving species in a working landscape: Land use with biological and economic objectives. *Ecological Applications, 15*(4), 1387-1401. doi:10.1890/03-5423

Prendergast, J. R., Quinn, R. M., & Lawton, J. H. (1999). The gaps between theory and practice in selecting nature reserves. *Conservation Biology, 13*(3), 484-492. doi:10.1046/j.1523-1739.1999.97428.x

Pressey, R. L. (1994). Ad hoc reservations - forward or backward steps in developing representative reserve systems. *Conservation Biology, 8*(3), 662-668. doi:10.1046/j.1523-1739.1994.08030662.x

Pressey, R. L., Humphries, C. J., Margules, C. R., Vanewright, R. I., & Williams, P. H. (1993). Beyond opportunism - key principles for systematic reserve selection. *Trends in Ecology & Evolution, 8*(4), 124-128. doi:10.1016/0169-5347(93)90023-I

Pressey, R., & Taffs, K. (2001). Scheduling conservation action in production landscapes: Priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. *Biological Conservation, 100*(3), 355-376. doi:10.1016/S0006-3207(01)00039-8

Radeloff, V. C., Hammer, R. B., & Stewart, S. I. (2005). Rural and suburban sprawl in the US Midwest from 1940 to 2000 and its relation to forest fragmentation. *Conservation Biology, 19*(3), 793-805. doi:10.1111/j.1523-1739.2005.00387.x

Radeloff, V., Hammer, R., Stewart, S., Fried, J., Holcomb, S., & McKeefry, J. (2005). The wildland-urban interface in the United States. *Ecological Applications, 15*(3), 799-805. doi:10.1890/04-1413

Radeloff, V. C., Stewart, S. I., Hawbaker, T. J., Gimmi, U., Pidgeon, A. M., Flather, C. H., Hammer, R. B., & Helmers, D. P. (2010). Housing growth in and near United States protected areas limits their conservation value. *Proceedings of the National Academy of Sciences of the United States of America, 107*(2), 940-945. doi:10.1073/pnas.0911131107

Rhemtulla, J. M., Mladenoff, D. J., & Clayton, M. K. (2007). Regional land-cover conversion in the US upper Midwest: Magnitude of change and limited recovery (1850-1935-1993). *Landscape Ecology, 22*, 57-75. doi:10.1007/s10980-007-9117-3

Sarkar, S., Pressey, R. L., Faith, D. P., Margules, C. R., Fuller, T., Stoms, D. M., & Andelman, S. (2006). Biodiversity conservation planning tools: Present status and challenges for the future. *Annual Review of Environment and Resources, 31*, 123-159. doi:10.1146/annurev.energy.31.042606.085844

Scott, J., Davis, F., McGhie, R., Wright, R., Groves, C., & Estes, J. (2001). Nature reserves: Do they capture the full range of America's biological diversity? *Ecological Applications, 11*(4), 999-1007. doi:10.2307/3061007

Spring, D. A., Cacho, O., Mac Nally, R., & Sabbadin, R. (2007). Pre-emptive conservation versus "fire-fighting": A decision theoretic approach. *Biological Conservation, 136*(4), 531-540. doi:10.1016/j.biocon.2006.12.024

Strange, N., Thorsen, B. J., & Bladt, J. (2006). Optimal reserve selection in a dynamic world. *Biological Conservation, 131*(1), 33-41. doi:10.1016/j.biocon.2006.02.002

Sutherland, W. J., Armstrong-Brown, S., Armsworth, P. R., Brereton, T., Brickland, J., Campbell, C. D., & Watkinson, A. R. (2006). The identification of 100 ecological questions of high policy relevance in the UK. *Journal of Applied Ecology, 43*(4), 617-627. doi:10.1111/j.1365-2664.2006.01188.x

Theobald, D. M., Hobbs, N. T., Bearly, T., Zack, J. A., Shenk, T., & Riebsame, W. E. (2000). Incorporating biological information in local land-use decision making: Designing a

system for conservation planning. *Landscape Ecology, 15*(1), 35-45. doi:10.1023/A:1008165311026

Theobald, D. M., Miller, J. R., & Hobbs, N. T. (1997). Estimating the cumulative effects of development on wildlife habitat. *Landscape and Urban Planning, 39*(1), 25-36. doi:10.1016/S0169-2046(97)00041-8

Town of Woodville. (2012). Expanded land use element, comprehensive amendment. Calumet County, Wisconsin. Retrieved June 20, 2013 from http://www.co.calumet.wi.us/documentcenter/view/9

Underwood, J. G., Francis, J., & Gerber, L. R. (2011). Incorporating biodiversity conservation and recreational wildlife values into smart growth land use planning. *Landscape and Urban Planning, 100*(1-2), 136-143. doi:10.1016/j.landurbplan.2010.11.014

US Fish and Wildlife Service. (2006). Guidelines for the State Wildlife Grant program. Retrieved 1 June 2013 from http://teaming.com/sites/default/files/SWG%20Guidelines.pdf.

Visconti, P., Di Marco, M., Alvarez-Romero, J. G., Januchowski-Hartley, S. R., Pressey, R. L., Weeks, R., and Rondinini, C. (2013). Effects of errors and gaps in spatial data sets on assessment of conservation progress. *Conservation Biology, 27*(5), 1000-1010. doi: 10.1111/cobi.12095

Visconti, P., Pressey, R. L., Bode, M., & Segan, D. B. (2010). Habitat vulnerability in conservation planning-when it matters and how much. *Conservation Letters, 3*(6), 404-414. doi:10.1111/j.1755-263X.2010.00130.x

Visconti, P., Pressey, R. L., Segan, D. B., & Wintle, B. A. (2010). Conservation planning with dynamic threats: The role of spatial design and priority setting for species' persistence. *Biological Conservation, 143*(3), 756-767. doi:10.1016/j.biocon.2009.12.018

WDNR (Wisconsin Department of Natural Resources). (2005). *Wisconsin's strategy for wildlife species of greatest conservation need, A State Wildlife Action Plan*. Madison, Wisconsin: Wisconsin Department of Natural Resources.

WDNR (Wisconsin Department of Natural Resources). (2008). *Wisconsin's wildlife action plan (2005-2015) implementation: Priority conservation actions and conservation opportunity areas*. Madison, Wisconsin: Wisconsin Department of Natural Resources.

WDNR (Wisconsin Department of Natural Resources). (2011). *Wisconsin endangered and threatened species laws & list.* (PUBL-ER-001). Madison, Wisconsin: Wisconsin Department of Natural Resources.

WDNR (Wisconsin Department of Natural Resources). (2012). *Ecological landscapes of Wisconsin.* (Handbook 1805.1). Madison, Wisconsin: Wisconsin Department of Natural Resources.

WDNR (Wisconsin Department of Natural Resources) Managed Lands (2013). Retrieved May 21, 2013 from http://dnr.wi.gov/maps/gis/geolibrary.html and from ftp://ftp.wi.gov/DNR/public/Lands/

Wilcove, D., Rothstein, D., Dubow, J., Phillips, A., & Losos, E. (1998). Quantifying threats to imperiled species in the United States. *Bioscience, 48*(8), 607-615. doi:10.2307/1313420

Wilson, K., Pressey, R. L., Newton, A., Burgman, M., Possingham, H., & Weston, C. (2005). Measuring and incorporating vulnerability into conservation planning. *Environmental Management, 35*(5), 527-543. doi:10.1007/s00267-004-0095-9

Wilson, K. A., McBride, M. F., Bode, M., & Possingham, H. P. (2006). Prioritizing global conservation efforts. *Nature, 440*(7082), 337-340. doi:10.1038/nature04366

Wilson, K. A., Underwood, E. C., Morrison, S. A., Klausmeyer, K. R., Murdoch, W. W., Reyers, B., & Possingham, H. P. (2007). Conserving biodiversity efficiently: What to do, where, and when. *Plos Biology, 5*(9), 1850-1861. doi:10.1371/journal.pbio.0050223

With, K. A., & Crist, T. O. (1995). Critical thresholds in species responses to landscape structure. *Ecology, 76*(8), 2446-2459. doi:10.2307/2265819

Withey, J. C., Lawler, J. J., Polasky, S., Plantinga, A. J., Nelson, E. J., Kareiva, P., & Reid, W. (2012). Maximising return on conservation investment in the conterminous USA. *Ecology Letters, 15*(11), 1249-1256. doi:10.1111/j.1461-0248.2012.01847.x

Wood, E. M., Pidgeon, A. M., Radeloff, V. C., Helmers, D., Culbert, P. D., Keuler, N. S., & Flather, C. H. 2014. Housing development erodes avian community structure in U.S. protected areas. *Ecological Applications, 24, 1445-1462.* http://dx.doi.org/10.1890/12-1992.1

Table 3. Description of priority area categories.

<table>
<tr><th></th><th>Low vulnerability (>67% of priority area is protected)</th><th>Medium vulnerability (33-67% of priority area is protected)</th><th>High vulnerability (<33% of priority area is protected)</th></tr>
<tr><td>Low threat[1]</td><td rowspan="3">Conservation strongholds</td><td>Low threat to existing investments</td><td>Promising opportunities for new, large-scale initiatives</td></tr>
<tr><td>Medium threat[2]</td><td rowspan="2">High threat to existing investments</td><td>Medium-term opportunities for conservation</td></tr>
<tr><td>High threat[3]</td><td>Narrow opportunities for conservation</td></tr>
</table>

[1]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.

[2] 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.

[3] 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.

Table 4. 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 3 for category definitions.

A. Wildlife Action Plan

	Low vulnerability	Medium vulnerability	High vulnerability
Low threat	Conservation strongholds: 26% (7,439.6 km^2)	Low threat to existing investments: 12% (3,262.2 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 vulnerability	Medium vulnerability	High vulnerability
Low threat	Conservation strongholds: 10% (6,349.1 km^2)	Low threat to existing investments: 10% (5,226.7 km^2)	Promising opportunities for new, large-scale initiatives: 26% (1,778.8 km^2)
Medium threat		High threat to existing investments: 8% (2,200.4 km^2)	Medium-term opportunities for conservation: 13% (866.1 km^2)
High threat			Narrow opportunities for conservation: 34% (2,143.4 km^2)

Table 5. Conservation status, considerations and actions for priority area categories. See Table 3 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, Wilson, Bode, & Possingham, 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.

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, Nelson, Lonsdorf, Fackler, & Starfield, 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.

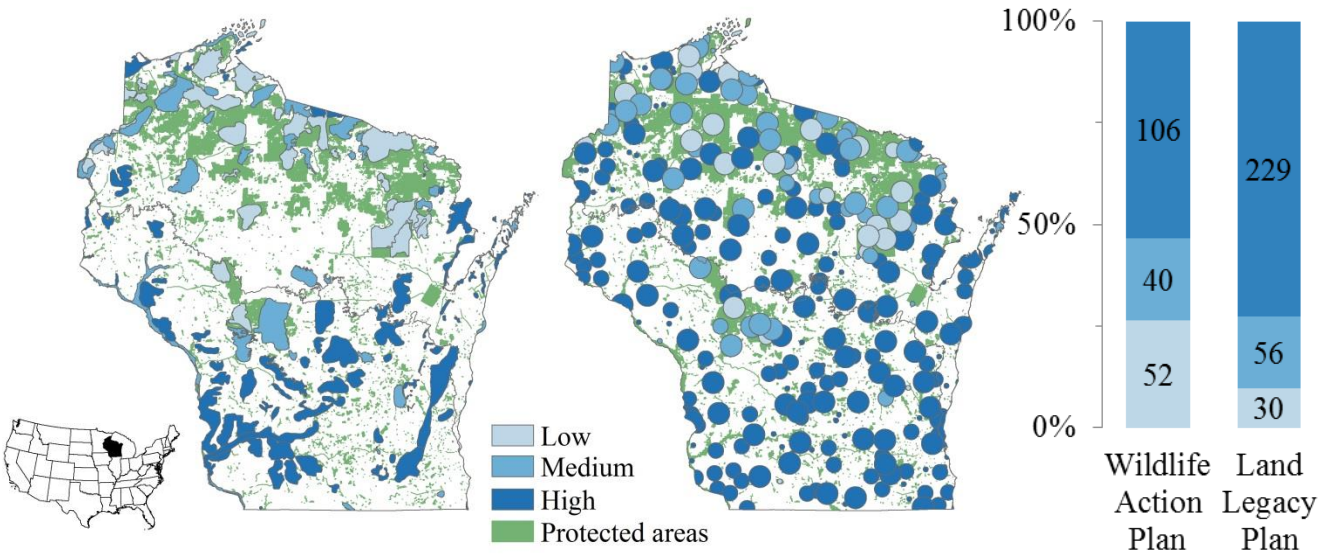

Figure 7. Vulnerability of priority areas in the Wildlife Action Plan (left) and Land Legacy Plan (right). The location of the state of Wisconsin within the United States is shown in the lower left corner. The ecological division between northern and southern Wisconsin is shown in dark grey. Bar graph indicates percentage (and number) of priority areas in each category.

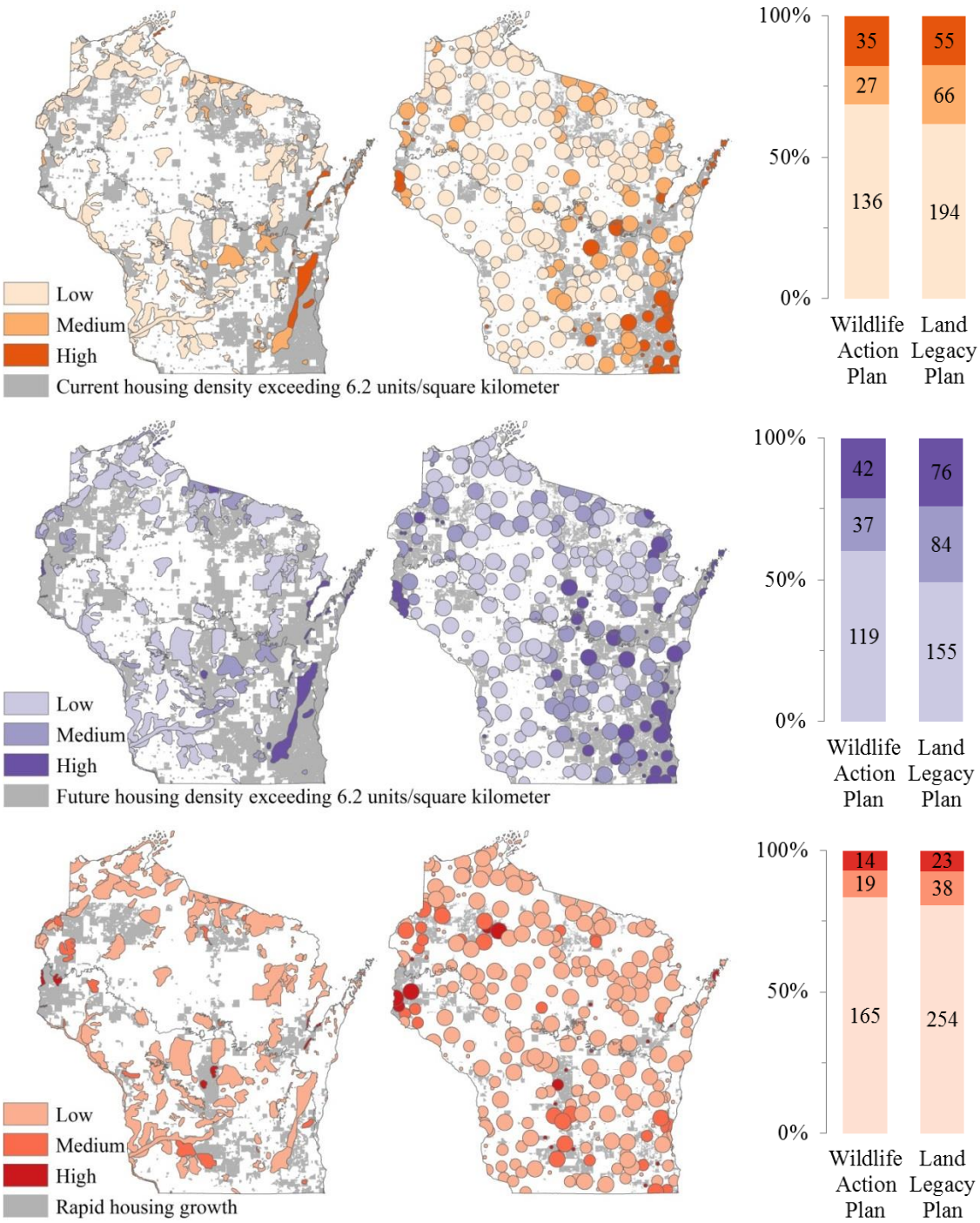

Figure 8. Threat to priority areas in the Wildlife Action (left) and Land Legacy (right) plans from current (top) and projected future (middle) housing densities > 6.2 units/km^2 and rapid housing growth (bottom). The ecological division between northern and southern Wisconsin is shown in dark grey. Bar graphs illustrate percentage (and number) of priority areas in each category.

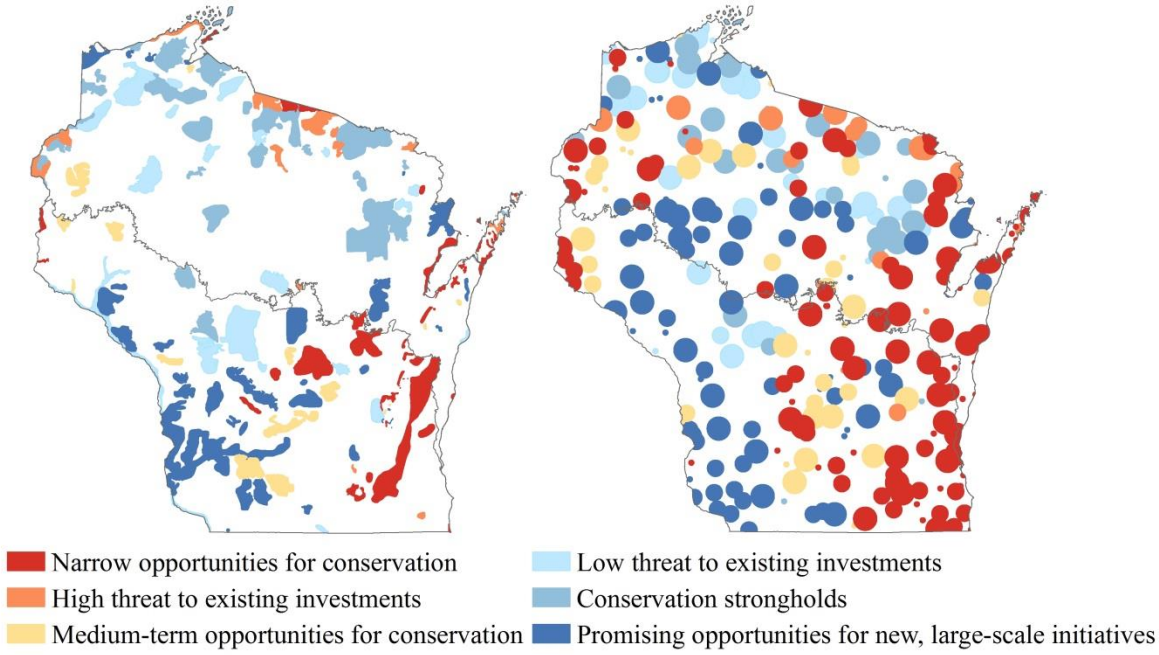

Figure 9. Categories of priority areas in the Wildlife Action Plan (left) and Land Legacy Plan (right). The ecological division between northern and southern Wisconsin is shown in dark grey. See Table 3 for category definitions.

Chapter 3: Institutional and policy factors influence conservation plan implementation

Abstract

Conservation plans are commonly used tools for prioritizing areas for protection, but plan implementation is often limited and rarely formally evaluated. Without evaluations of planning outcomes, it is difficult to justify the resources expended in developing plans and to adapt future plans so that they are more likely to achieve desired conservation outcomes. We evaluated implementation of four conservation plans in Wisconsin, USA, by quantifying land protection by the state resource management agency within plan boundaries over time. We then asked which environmental, institutional, and socio-economic factors best explained implementation of the most recent (2008) plan. We created a conceptual model of the implementation process to aid in identifying relevant metrics for our analysis. In our model, successful plan implementation depends upon five major considerations: land availability, agency land protection policies, agency implementation plans, broad-based support for land protection (from the agency, partners, local government, and the public), and additional factors considered by agency oversight bodies in granting final approval of land protection transactions. We then used boosted regression trees to identify the metrics important in explaining where land protection has occurred successfully inside the boundaries of the most recent plan since its completion. We found that 11% and 45% of lands inside plan boundaries have been protected by the agency and by other partners, respectively, compared to protection of 2% and 5% of all lands outside plans. Our model explained 61% of the variability in implementation within the current plan. Key factors explaining implementation success were 1) prior successful land protection efforts (an indicator of agency and broader-based support for land protection), 2) having agency authorization for land protection in place prior to plan completion, and 3) the presence of open

water. The latter two factors are both priorities in the agency's land protection policy. Our findings demonstrate the importance of considering institutional and policy factors in developing conservation plans, so that identified priority areas are more likely to correspond with on-the-ground implementation opportunities.

Introduction

Conservation plans (hereafter, plans) are commonly used tools both by governmental agencies and non-governmental conservation organizations worldwide. Plans are intended to guide conservation actions, and to provide a framework for evaluating conservation achievements (Bottrill & Pressey 2012). Unfortunately, relatively few plans are implemented, and in few cases are implemented actions considered highly effective (Knight et al 2008), leading to what has been termed the planning-implementation gap or implementation crisis (Knight et al. 2008). Formal evaluation of plan implementation is still rare (Bottrill & Pressey 2012), making it difficult to justify continued resource expenditures for developing new plans (Groves et al. 2002) and impeding the adaptive management process (Grantham et al. 2010). Here we quantify implementation of multiple plans, and identify environmental, institutional and socio-economic factors associated with successful implementation of a recent plan.

Biodiversity conservation can be achieved through a variety of actions, including species and habitat management, policy and legislation, education, training/capacity building, and research (Kapos et al. 2009). Land protection continues to be the backbone of many conservation strategies (Bengston et al. 2004), and is one of the primary outcomes expected by staff and stakeholders developing conservation plans (Bottrill et al. 2012). Thus evaluating land protection within plan boundaries is one approach for quantifying implementation success (Bottrill & Pressey 2012).

Conservation action, including land protection, occurs within a socio-economic and institutional context that affects both conservation opportunities and the ability and willingness of agencies and organizations to act on those opportunities (Cowling & Wilhelm-Rechmann 2007). Politics, economics, and social conditions at local, regional, and national scales shape opportunities for

conservation action (Knight et al. 2011a; Radeloff et al. 2013, Moon et al. in press). Land ownership and tenure patterns may limit opportunities for land protection within a region (Knight et al. 2011b). Ineffective stakeholder involvement during the planning process can lead to low acceptance of plans and limited support for their implementation (Martin et al. 2012). A lack of resources within participating organizations may also limit implementation opportunities, particularly when proposed actions include land protection, which is staff and funding intensive (Knight et al. 2011a). Agency missions as well as broader societal concerns may require that lands protected for biodiversity serve additional purposes, such as supporting local economies (Sunderlin et al. 2005). Agency policies may also define priorities (e.g., US Fish and Wildlife Service 2014) or impose limitations (e.g., Wis. Admin. Code NR §1.41, see Appendix A) on where land can be protected at both broad and local scales. Being aware of and explicitly accounting for these socio-economic and institutional factors in planning processes is critical for the success of conservation plans and programs (Ban et al., 2013; Faleiro & Loyola 2013).

Our two objectives were 1) to evaluate to what extent past plans have been implemented, and 2) to identify what environmental, institutional and socio-economic factors best explain where recent implementation efforts have been successful. We assessed implementation by quantifying land protection within plan boundaries for four plans using more than a century of land protection records. We developed a conceptual model of the plan implementation process to facilitate identification of relevant environmental, institutional and socio-economic metrics. We then evaluated factors explaining implementation success of the most recent (2008) plan. Our analysis used existing spatial datasets that are likely to be available in other regions to facilitate application of our approach to other locations.

Methods

Study area

Wisconsin is a biologically diverse state in the north-central United States covering approximately 145,000 km^2. Southern Wisconsin was historically dominated by tallgrass prairies and oak savannas, while northern hardwood forests dominate northern Wisconsin. Current 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 et al. 2005). Wisconsin's state management agency has a long history of conservation planning and land protection, dating back more than a century, and continues to actively protect land each year (Carter et al. 2014a).

Evaluating implementation of conservation plans

Statewide, spatially-explicit conservation plans were completed for Wisconsin in 1939, 1964, 2004, and 2008 (Wisconsin State Planning Board and Conservation Commission 1939, National Park Service 1964, Pohlman et al. 2006, WDNR 2008). All four plans were expert-based and were led by or developed in close collaboration with the state natural resource management agency (the Wisconsin Department of Natural Resources (WDNR), Appendix B). Criteria for identifying priority areas within plans were primarily biological (e.g., high-quality natural areas, important populations of rare species), but also included recreation, water quality, scenic, scientific, geologic, and historic value (Appendix B).

We quantified plan implementation using land protection data from three sources: 1) lands protected by WDNR between 1876 and 2013 (WDNR 2013a), 2) additional lands protected by other entities (Conservation Biology Institute 2012), and 3) conservation easements held by other

entities (National Conservation Easement Database 2012). We defined protected lands as all lands publicly owned, with conservation easements, or within tribal reservations. We calculated the cumulative area of land protected annually by WDNR within each of the four plan boundaries over time. We also calculated the total area of land protected as of 2013 within and outside of plan boundaries by WDNR and by all agencies and conservation organizations combined.

Identifying factors explaining plan implementation

Drawing on the most recent conservation plan (2008) for Wisconsin and our collective experience in planning, land protection, and natural resources management, we conceptualized steps in the decision making process that lead to implementation via land protection (Figure 10), and used this framework to identify factors potentially explaining whether or not land was subsequently protected within plan boundaries. We identified five main conditions that need to be met before an agency (in this case WDNR) can successfully protect land within the boundaries of an existing conservation plan. We present these conditions in the form of questions. A positive response to each question is generally required to move to the next question, ultimately resulting in a successful land protection transaction. A negative response to any of the main considerations decreases the likelihood (sometimes to zero) that the transaction will be successful. First, is there land available to protect? If all land within an identified plan priority area is already protected, no land protection can occur. Many conservation plans include as priorities some areas that are already largely or completely protected, which are priorities for other reasons (e.g., land management, Carter et al. 2014b). Second, is the available land a priority according to the laws, administrative code, or formal policies that guide agency land protection? Land that does not rank highly by agency laws, administrative code, or policies, is

unlikely to be protected (e.g., US Fish and Wildlife Service 2014). Third, does the available land also rank highly according to existing agency implementation plans? While conservation plans are often written for broad audiences, ideally they are followed up by specific implementation plans in which an agency commits to implementing (and allocates resources for) a specific subset of projects identified in the conservation plan within a specified time frame (Carter et al. 2014a). Fourth, does the agency, its partners, government, and the public (especially locally) support protecting the land? Broad-based stakeholder support is generally necessary for successful plan implementation (Knight et al. 2011a). Finally, does the parcel for which protection is being requested meet economic and other criteria that government oversight boards or executives consider when granting final approval for a land protection transaction?

Using our conceptualization as a guide, we collated measurable environmental, institutional and socio-economic variables that related to each of the considerations that we had identified as influencing implementation of land protection. We relied on existing spatial datasets, many of which are available across the USA and are also available in other regions (e.g., landcover, population density, election statistics). We collated 20 variables in total (Table 6) for each of the 231 priority areas in the 2008 plan. Pairwise correlations for all explanatory variables were $\leq |0.64|$.

We then evaluated which metrics were most strongly associated with implementation of the 2008 plan. We modeled whether or not land protection occurred in each priority area after plan completion based on the 20 explanatory metrics using boosted regression trees (BRT, Elith et al. 2008) with a binary response variable. We limited our assessment to lands protected by the WDNR, as we had transaction dates only for this set of land parcels. We fit the BRT models using a learning rate of 0.005, a tree complexity of three, and a bag fraction of 0.75 using the

gbm package (Ridgeway 2013) in R (R Core Team 2013), and code written by Elith et al. (2008). We used ten-fold cross-validation to identify the optimal number of trees for the model (Elith et al., 2008). The importance of each explanatory variable was evaluated based on the contribution to model fit attributable to each explanatory variable, averaged across all trees (Friedman et al., 2000).

Results

Evaluating implementation of conservation plans

We found that WDNR protected between 3% and 10% of lands inside plan boundaries prior to plan completion, and has now protected a total of between 10% and 12% of lands inside plan boundaries (Table 7). Land protection has continued through the present for all four plans, representing a total protection timeframe of more than a century (Figure 11). Land protection to date by all agencies and organizations combined averaged 44% of lands inside plan boundaries (Table 7, Figure 11). In comparison, 1.6% and 5.1% of lands outside of the boundaries of all plans have been protected to date by WDNR and by all agencies and organizations combined, respectively.

Identifying factors explaining plan implementation

WDNR has protected land in 42% of the priority areas identified in the 2008 plan (Figure 12). All predictive factors in the BRT model showed a substantial range of variability among the 231 priority areas in the 2008 plan (Table 7). The final BRT model explained 61% of the variability in priority areas where land protection has and has not occurred since plan completion. The top factors associated with protection occurring within a priority area fell into two categories: support for land protection and agency policy (Table 8). The top three explanatory variables

were the percentage of each priority area already protected by WDNR prior to plan completion (an indicator of agency and broad-based support for land protection, importance value 34%), the percentage of the priority area within the the boundary of an approved WDNR land protection project and available (the second highest priority in agency policy, importance value 26%), and the percentage of the priority area in open water (the fifth highest priority in agency policy, importance value 10%; Table 8, Figure 12).

A second tier of variables with lower importance values (~4%) also related to support for land protection from the public, partners, and local government (Table 8). However, re-running the model excluding this second tier of variables (and all other variables with lower importance scores) explained the same amount of variability in implementation as the full model (61%). The highest priority in agency policy, protecting lands in densely populated areas (Appendix A), was not important in explaining implementation success (importance value <1%, Table 8).

Fitted functions provide a useful basis for interpreting the characteristics of priority areas for which implementation is most likely. Fitted functions for the top three variables in our model indicated that implementation was most strongly associated with priority areas in which roughly 10% or more of the area is 1) already protected by WDNR, 2) both unprotected and within the boundary of an approved WDNR land protection project, and 3) open water (Figure 13).

Discussion

We examined implementation of four conservation plans developed by a state natural resources management agency and identified factors associated with successful implementation of the most recent plan, completed in 2008. We found that 10 and 45% of the lands within plan boundaries are currently protected by WDNR and by all partners combined, respectively. Implementation

success of the most recent plan was best explained by where WDNR had already established agency-specific land protection projects and successfully protected land before plans were completed.

Evaluating implementation of conservation plans

Conservation agencies and organizations have protected nearly half of the land within the boundaries of conservation plans for the state of Wisconsin. Habitat loss and fragmentation from housing development and other forms of land use change are the major threats to biodiversity in the state (WDNR 2005), and nearly all lands considered to be protected in this analysis prohibit development (the exception is some tribal lands on which development may occur). The priority areas in the plans examined represent sites of biological importance (e.g., areas with high concentrations of rare species, Appendix B), suggesting an important role for conservation plans and protected areas in biodiversity conservation in Wisconsin. Specific conservation targets and measurable conservation goals are needed, however, to evaluate whether this land protection is achieving long-term conservation goals in the state (Margules et al. 2002).

The current level of land protection within plan boundaries took many years to achieve, indeed up to 70 years for the earliest plan which has the highest percentage of land protected (58%). For all plans, land protection began before plans were completed, likely due in part to the substantial overlap in plan boundaries (e.g., 90% of priority areas in the 2008 plan were partially or entirely encompassed by a previous plan) and WDNR's policy prioritizing the completion of existing projects over the development of new ones (Appendix A). Land protection inside plan boundaries continues through the present, in contrast with some marine conservation planning efforts, where protection occurred almost immediately upon plan completion (Fernandes et al. 2005; Gleason et al. 2010). The pattern of gradual protection over time observed here suggests

that effective protection of newly identified priority areas that are highly threatened may be difficult to achieve. Instead an approach in which protection is targeted toward areas of high conservation value which are not yet highly threatened may ultimately provide the best opportunity to achieve long term conservation goals (Visconti et al. 2010).

WDNR protected land inside the boundaries of all four plans examined, which is consistent with findings that implementation rates are modest (33%) among all published plans, but substantially higher (94%) when considering only those plans whose primary objective was to implement action (versus a primary objective of research, for example; Knight et al 2008).

Identifying factors explaining plan implementation

Environmental factors such as land productivity, altitude, and distance from cities are strongly reflected in the protected areas of the US and worldwide (Scott et al. 2001; Joppa & Pfaff 2009). Ineffective stakeholder involvement, low capacity, and a lack of consideration of the social aspects of conservation may also influence the feasibility of land protection and other conservation actions identified in plans (Knight et al. 2008; Knight et al. 2011a; Bottrill et al. 2012). Our findings lend strong, quantitative support to the importance of broad-based support for successful implementation of agency plans. State and federal laws (e.g., US National Environmental Policy Act of 1969) often require extensive opportunities for public comment on proposed government activities, and significant opposition (especially locally) can effectively kill an otherwise viable land protection opportunity (JP, *unpublished data*). A prior successful land protection transaction may well be the strongest evidence of existing broad-based support for current land protection efforts, and was the most important factor explaining implementation success here.

We also found that agency policy limited WDNR's capacity to protect land inside plan boundaries in the short term. Specifically, implementation within six years was more likely to occur where WDNR already had the authority to acquire land before the plan was developed. WDNR's acquisition authority is largely limited to lands within the boundaries of approved local land protection projects (Wis. Admin. Code NR §1.41, Appendix A). Such projects can take years or even decades to establish (WDNR 2013), and are a relevant step in the land protection processes of federal agencies (e.g., US Fish and Wildlife Service National Wildlife Refuge System, D. Granholm, *pers. comm.*) and non-governmental conservation organizations (e.g., The Nature Conservancy, Bottrill et al. 2012) as well. Implementation activities other than land protection (e.g., inventory, education, outreach) may not be subject to the same policy restrictions on capacity, but data on such activities are not available.

The importance of open water in explaining implementation success reinforces the importance of considering agency policy during the planning process, and suggests a role for greater consideration of areas where recreational and conservation interests align (Thomas 2010). The potential for water-based recreation may bring additional stakeholder groups to the table (e.g., anglers, kayakers), providing a broader base of support for land protection.

Notably, the top priority in agency policy, protection of land in densely populated areas (Appendix A), was not an important variable in our model. A related policy priority, protecting land near large cities, was also not important. Both findings illustrate the not uncommon conflicts between different facets of the land protection process. While policy may prioritize protection of land near cities, land near cities also tends to be more costly and may harbor fewer endangered species, both factors with a potential negative affect on the ultimate likelihood of the land protection transaction being approved (Table 6).

Conclusion

Conservation biology has been criticized as an academic endeavor that has had little impact on real world activities (Whitten et al. 2001). Given the small proportion of plans effectively implemented to date (Knight et al. 2008), the same might be said of conservation planning. Our study has provided a quantitative assessment of plan implementation and of factors associated with implementation success. Planners can use this information in an adaptive management process to help identify where conservation practitioners are most likely to be able to protect areas identified as being of high biological importance in current conservation plans, and to help develop future plans which consider (in addition to biology) key institutional and policy factors likely to correspond positively with on-the-ground implementation opportunities.

References

Ban, N. C., M. Mills, J. Tam, C. C. Hicks, S. Klain, N. Stoeckl, M. C. Bottrill, J. Levine, R. L. Pressey, T. Satterfield, and K. M. A. Chan. (2013). A social-ecological approach to conservation planning: embedding social considerations. *Front. Ecol. Environ.*, **11**:194-202.

Bengston, D. N., J. O. Fletcher, & K. C. Nelson. (2004). Public policies for managing urban growth and protecting open space: policy instruments and lessons learned in the United States. *Landscape Urban Plan.,* **69**, 271.

Bottrill, M. C., M. Mills, R. L. Pressey, E. T. Game, & C. Groves. (2012). Evaluating perceived benefits of ecoregional assessments. *Cons. Biol.,* **26**, 851-861.

Bottrill, M. C., & R. L. Pressey. (2012). The effectiveness and evaluation of conservation planning. *Cons. Lett.,* **5**, 407.

Bultena, G. L., & E. O. Hoiberg. (1983). Factors affecting farmers' adoption of conservation tillage. *J. Soil Water Conserv.,* **38**, 281-284.

Carter, S. K., N. S. Keuler, A. M. Pidgeon, & V. C. Radeloff. (2014a). Evaluating the influence of conservation plans on land protection actions in Wisconsin, USA. *Biol. Cons.,* **178**, 37-49.

Carter, S. K., J. D. Pohlman, T. L. Bergeson, C. M. Hamilton, A. M. Pidgeon, & V. C. Radeloff. (2014b). Improving the utility of existing conservation plans using projected housing development. *Landscape Urban Plan.,* **126**, 10-20.

Conservation Biology Institute. (2012). Protected Areas - Wisconsin, USA. Corvallis, Oregon. Available from http://consbio.org/products/projects/pad-us-cbi-edition. Accessed 2 November 2012.

Cowling, R. M., & A. Wilhelm-Rechmann. (2007). Social assessment as a key to conservation success. *Oryx,* **41**, 135-136.

Elith, J., J. R. Leathwick, & T. Hastie. (2008). A working guide to boosted regression trees. *J. Anim. Ecol.,* **77**:802-813.

Faleiro, F. V., & R. D. Loyola. (2013). Socioeconomic and political trade-offs in biodiversity conservation: A case study of the Cerrado Biodiversity Hotspot, Brazil. *Divers. Distrib.,* **19**, 977-987.

Fernandes, L., J. Day, A. Lewis, S. Slegers, B. Kerrigan, D. Breen, D. Cameron, B. Jago, J. Hall, D. Lowe, J. Innes, J. Tanzer, V. Chadwick, L. Thompson, K. Gorman, M. Simmons, B. Barnett, K. Sampson, G. De'ath, B. Mapstone, H. Marsh, H. Possingham, I. Ball, T. Ward, K. Dobbs, J. Aumend, D. Slater, & K. Stapleton. (2005). Establishing representative no-take areas in the Great Barrier Reef: Large-scale implementation of theory on marine protected areas. *Cons. Biol.,* **19**, 1733.

Friedman, J.H., Hastie, T. & Tibshirani, R. (2000). Additive logistic regression: a statistical view of boosting. *Ann. Stat.,* **28**, 337–407.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., & Wickham, J. (2011). Completion of the 2006 National Land Cover Database for the Conterminous United States. *Photogramm. Eng. Rem. S.*, **77**, 858-864.

Gleason, M., S. McCreary, M. Miller-Henson, J. Ugoretz, E. Fox, M. Merrifield, W. McClintock, P. Serpa, & K. Hoffman. (2010). Science-based and stakeholder-driven marine protected area network planning: A successful case study from north central California. *Ocean Coast. Manage.,* **53**, 52-68.

Grantham, H. S., M. Bode, E. McDonald-Madden, E. T. Game, A. T. Knight, & H. P. Possingham. (2010). Effective conservation planning requires learning and adaptation. *Front. Ecol. Environ.,* **8**, 431-437.

Groves, C. R., D. B. Jensen, L. L. Valutis, K. H. Redford, M. L. Shaffer, J. M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, & M. G. Anderson. (2002). Planning for biodiversity conservation: Putting conservation science into practice. *Bioscience,* **52**, 499.

Herreid, P.E. (2011). 2011 Wisconsin local land use regulations and comprehensive planning status report. Available from http://www.doa.state.wi.us/Divisions/Intergovermental-Relations/Comprehensive-Planning/2011-Land-Use-Regs-and-Planning-Status-Inventory-Report. Accessed 27 January 2014.

Joppa, L. N., & A. Pfaff. (2009). High and far: Biases in the location of protected areas. *Plos One,* **4**, e8273.

Kapos, V., A. Balmford, R. Aveling, P. Bubb, P. Carey, A. Entwistle, J. Hopkins, T. Mulliken, R. Safford, A. Stattersfield, M. Walpole, & A. Manica. (2009). Outcomes, not implementation, predict conservation success. *Oryx*, **43**, 336-342.

Knight, A. T., R. M. Cowling, A. F. Boshoff, S. L. Wilson, & S. M. Pierce. (2011a). Walking in STEP: Lessons for linking spatial prioritisations to implementation strategies. *Biol. Cons.*, **144**, 202-211.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, & B. M. Campbell. (2008). Knowing but not doing: Selecting priority conservation areas and the research-implementation gap. *Cons. Biol.,* **22**, 610.

Knight, A. T., H. S. Grantham, R. J. Smith, G. K. McGregor, H. P. Possingham, & R. M. Cowling. (2011b). Land managers' willingness-to-sell defines conservation opportunity for protected area expansion. *Biol. Cons.*, **144**, 2623-2630.

Kroetz, K., J. N. Sanchirico, P. R. Armsworth, & H. S. Banzhaf. (2014). Benefits of the ballot box for species conservation. *Ecol. Lett.,* **17**, 294-302.

Levin, S., T. Xepapadeas, A.-S. Crepin, J. Norberg, A. De Zeeuw, C. Folke, T. Hughes, K. Arrow, S. Barrett, G. Daily, P. Ehrlich, N. Kautsky, K.-G. Maler, S. Polasky, M. Troell, J. R. Vincent, & B. Walker. (2013). Social-ecological systems as complex adaptive systems: Modeling and policy implications. *Environ. Dev. Econ.*, **18**, 111-132.

Margules, C. R., R. L. Pressey, & P. H. Williams. (2002). Representing biodiversity: Data and procedures for identifying priority areas for conservation. *J. Biosciences*, **27**, 309-326.

Martin, T. G., S. Nally, A. A. Burbidge, S. Arnall, S. T. Garnett, M. W. Hayward, L. F. Lumsden, P. Menkhorst, E. McDonald-Madden, & H. P. Possingham. (2012). Acting fast helps avoid extinction. *Cons. Lett.*, **5**, 274-280.

Minnesota Population Center. (2011). National Historical Geographic Information System: Version 2.0. Minneapolis, MN: University of Minnesota. Available from https://www.nhgis.org/. Accessed 23 May 2014.

Moon, K., Adams, V., Januchowski-Hartley, S.R., Polyakov, M. Biggs, D. Game, E., Mills, M., Knight, A. and Raymond, C. A multidisciplinary conceptualization of conservation opportunity. *Cons. Biol., In Press*.

Moon, K., N. Marshall, & C. Cocklin. (2012). Personal circumstances and social characteristics as determinants of landholder participation in biodiversity conservation programs. *J. Environ. Manage.*, **113**, 292-300.

National Conservation Easement Database. (2012). West Linn, Oregon. Available from http://www.conservationeasement.us. Accessed 31 October 2012.

National Park Service. (1964). Parks for America: a survey of park and related resources in the fifty states, and a preliminary plan. US Department of the Interior, Washington, D.C.

Pohlman, J. D., G. A. Bartelt, A. C. Hanson, III, P. H. Scott, & C. D. Thompson, eds. (2006). Wisconsin Land Legacy Report: An inventory of places to meet Wisconsin's future conservation and recreation needs. Wisconsin Department of Natural Resources, Madison, WI.

R Core Team. (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from http://www.R-project.org/.

Radeloff, V. C., F. Beaudry, T. M. Brooks, V. Butsic, M. Dubinin, T. Kuemmerle, & A. M. Pidgeon. (2013). Hot moments for biodiversity conservation. *Cons. Lett.,* **6**, 58-65.

Radeloff, V. C., R. B. Hammer, & S. I. Stewart. (2005). Rural and suburban sprawl in the US Midwest from 1940 to 2000 and its relation to forest fragmentation. *Cons. Biol.,* **19**, 793.

Radeloff, V. C., S. I. Stewart, T. J. Hawbaker, U. Gimmi, A. M. Pidgeon, C. H. Flather, R. B. Hammer, & D. P. Helmers. (2010). Housing growth in and near United States protected areas limits their conservation value. *P. Natl. Acad. Sci. USA,* **107**, 940.

Ridgeway, G. (2013) Generalized Boosted Regression Models. Available at: http://cran.rproject.org/web/packages/gbm/index.html. Accessed 1 August 2014.

Scott, J. M., F. W. Davis, R. G. McGhie, R. G. Wright, C. Groves, & J. Estes. (2001). Nature reserves: Do they capture the full range of America's biological diversity? *Ecol. Appl.,* **11**, 999.

Sunderlin, W. D., A. Angelsen, B. Belcher, P. Burgers, R. Nasi, L. Santoso, & S. Wunder. (2005). Livelihoods, forests, and conservation in developing countries: An overview. *World Dev.*, **33**, 1383-1402.

Thomas, S. L. (2010). When Equity Almost Mattered: Outdoor recreation, land acquisition, and mid-twentieth-century conservation politics. *Nat. Resour. J.,* **50**, 501-516.

US Fish and Wildlife Service. (2014). Strategic Growth Policy for the National Wildlife Refuge System. US Fish and Wildlife Service Manual: 602 FW 5. Available from http://www.fws.gov/policy/602fw5.pdf. Accessed 3 October 2014.

Visconti, P., R. L. Pressey, D. B. Segan, & B. A. Wintle. (2010). Conservation planning with dynamic threats: The role of spatial design and priority setting for species' persistence. *Biol. Cons.*, **143**, 756.

US Department of Agriculture National Agricultural Statistics Service. (2014). Agricultural Land Sales Summaries and Forest Land Sales for years 2008 – 2012. Available from http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Land_Sales/. Accessed 5 May 2014.

WDNR. (2005). Wisconsin's strategy for wildlife species of greatest conservation need: A state wildlife action plan. Wisconsin Department of Natural Resources, Madison, WI.

WDNR. (2008). Wisconsin's wildlife action plan (2005-2015) implementation: priority conservation actions and conservation opportunity areas. Wisconsin Department of Natural Resources, Madison, WI.

WDNR. (2013). Feasibility Studies. Available from http://dnr.wi.gov/topic/lands/masterplanning/Feasibility.html. Accessed 12 November 2013.

WDNR (2013a). Lands owned or managed by WDNR. Available from http://dnr.wi.gov/maps/gis/geolibrary.html and from ftp://ftp.wi.gov/DNR/public/Lands/. Accessed 21 May 2013.

WDNR (2013b). Private lands enrolled in the WDNR Managed Forest Law Program. Available from Division of Forestry, Wisconsin Department of Natural Resources, Madison, WI.

Whitten, T., D. Holmes, & K. MacKinnon. (2001). Conservation biology: a displacement behavior for academia? *Cons. Biol*., **15**:1.

Wisconsin Government Accountability Board (2006). 2006 election data by ward. Available from http://legis.wisconsin.gov/ltsb/redistricting/2006_election_data.htm. Accessed 6 June 2014.

Wisconsin State Planning Board and Conservation Commission. (1939). A park, parkway and recreational area plan. Wisconsin State Planning Board and Conservation Commission, Madison, WI.

Table 6. Predictive factors identified for each component of the conceptual model in Figure 10. These factors were used to model implementation of priority areas within the 2008 conservation plan.

Metric	**Description**	**Spatial resolution and source of data**	**Mean and range**
Land availability: Is there land available to protect?			
Land not already protected	Proportion of each priority area not protected by the state agency prior to plan completion, or in federal or tribal ownership.[1]		0.7 (0.001-1.0)
Age	Spatially-weighted average proportion of population over 65. We considered a greater proportion of the population near retirement age as an indicator of a greater likelihood of private (unprotected) lands becoming available for sale.	US Census block group, Minnesota Population Center 2011	0.2 (0.1-0.4)
Agency policy: Is land a priority by agency law/policy?[2]			
Population	NR 1.40(1), contained in Appendix A, specifies that the department shall place principal emphasis on	US Census block group,	25.3 (1.1-

density	lands in heavily populated areas. We computed the spatially averaged population density within the priority area.	Minnesota Population Center 2011	412.7)
Existing WNDR land protection projects	NR 1.40(2)(a) specifies that the department shall prioritize consolidation and completion of existing projects. We computed the proportion of each priority area that is both unprotected and inside of current WDNR project boundaries.	WDNR 2013a	0.2 (0.0-1.0)
Endangered resources	NR 1.40(2)(b)(1) specifies that the department shall next prioritize protection of rare and threatened natural resources. We used the ecological significance of each priority area (1=statewide, 2=Midwest region, 3=continental, 4=global) designated in the plan.	WDNR 2008	2.8 (1-4)
Landcover (water, wetlands, forests)	NR 1.40(2)(b)(3) specifies that the department shall next prioritize protection of water-based resources. NR 1.40(2)(c)(1,4) specifies that the department shall not prioritize protection of wetlands or forests that do not meet other criteria. We calculated the proportion of each priority area covered by open water, wetlands, and forests.	30 m x 30 m pixels, Fry et al., 2011	Water: 0.05 (0.0-0.8), Wetlands: 0.2 (0.0-0.7), Forest: 0.4 (0.0-

			1.0)
Proximity to cities	NR 1.40(2)(b)(5) specifies that the department shall next prioritize protection of lands within 40 miles of Wisconsin's 12 largest cities. We computed whether the edge of the priority area was within 64.4 km of the centroid of the 12 largest cities in Wisconsin using the near function in ArcGIS 10.1 (1=yes, 0=no).		0.43, 0-1
Agency plans: Does the land rank highly in agency plans?			
Identified implement-tation priorities	We were not able to identify metrics for this component of the model, as the agency has not developed an agency-specific implementation plan for the 2008 conservation plan.		
Support: Does broad-based support (i.e., from the agency, partners, government, and the public) for land protection exist?			
Support from the agency (dominantly) and also from partners, government, and the public			
Extent protected by WDNR	Proportion of priority area protected by the agency before plan completion (i.e., 2007 and before). We viewed previous successful land protection by the agency as an indication of both agency and broad-	WDNR 2013a	0.1 (0.0-1.0)

	based support, as land transactions must ultimately have both to be approved (JP, *unpublished data*). However successful land protection by the agency, particularly after World War II, suggests a broader positive response to other components of our conceptual model as well.		
Support from conservation partners			
Partner conservation easements	Proportion of priority area currently under a conservation easement held by an entity other than the WDNR. We considered enrollment of private lands in partner-held easements to be an indicator of active partner involvement.	National Conservation Easement Database 2012	0.007 (0.0-0.4)
Support from local government			
Land use planning	Proportion of priority area for which a comprehensive land use plan was adopted by November 2010 (the state deadline). Approved land use plans indicate general support from the community for land use planning, which includes protection of open space and conservation values (P. Herreid, *pers. comm.*).	city/village, township, or county; Herreid 2011	0.7 (0.0-1.0)
Zoning	Proportion of priority area for which zoning	city/village,	0.4 (0.0-

regulations	regulations are in place. Zoning regulations indicate a willingness in the community to designate specific areas on the landscape to meet specific purposes, including conservation and protection of open space (P. Herreid, *pers. comm*.).	township, or county; Herreid 2011	1.0)
Support from the public			
Private lands conservation behavior	Proportion of priority area currently enrolled in the WDNR Managed Forest Law Program. We considered enrollment of private lands in this program to be an indicator of willingness to consider conservation in their land management actions and willingness to work with the WDNR.	0.16 km^2 (40 acre) blocks, WDNR 2013b	0.1 (0.0-0.7)
Political affiliation	Spatially-weighted average proportion of population voting liberal (democratic, green party) in 2006 gubernatorial election. Political affiliation has been shown to be related to support for conservation action (Kroetz et al. 2014).	Voting wards, Wisconsin Government Accountability Board 2006	0.5(0.2-0.8)

Income	Spatially-weighted average mean household income, which can be related to support for conservation action (Bultena & Hoiberg 1983; Kroetz et al. 2014).	US Census block group, Minnesota Population Center 2011	52,296 (30,539-90,427)
Education	Spatially-weighted average proportion of population with a Bachelor's degree or higher, which can be related to support for conservation action (Bultena & Hoiberg 1983; Kroetz et al. 2014; Moon et al. 2012).	US Census block group, Minnesota Population Center 2011	0.2 (0.05-0.8)
Final approval: Is the transaction likely to receive final approval?			
Land cost	Spatially-weighted average cost of forest (for northern Wisconsin) or agricultural (for southern Wisconsin) land for 2008-2012. Land cost per unit area is a key consideration of the agency oversight board in approving individual land protection transactions (JP, *unpublished data*).	County, USDA National Agricultural Statistics Service 2014	3,264 (365-12,287)
Threat (projected housing	We computed two metrics of threat from projected housing development: proportion of priority area with 1) a housing density projected to exceed 1 house	US Census partial block group,	Housing density: 0.1 (0.0-

density, projected housing growth)	per 40 acres by 2030, and 2) a projected housing growth rate projected to exceed 50% between 2000 and 2030 (Carter et al. 2014b). Threat is a consideration of the agency oversight board in approving individual land protection transactions (JP, *unpublished data*), and housing development is currently the major threat to habitat in Wisconsin (Radeloff et al. 2005).	Radeloff et al. 2010	1.0), Housing growth: 0.05 (0.0-1.0)

[1] Dates for land protected by local agencies or conservation organizations are not available.

[2]Additional priorities in the policy were difficult to quantify (e.g., NR 1.40 (2)(b)(2), 'one-of-a-kind opportunities', see Appendix A) and are not analyzed here.

Table 7. Conservation plan implementation via land protection in Wisconsin, USA.

Year plan completed	Area in plan (km^2, percent of state)	Total area protected by WDNR[1] within plan boundary (km^2, percent of plan area) prior to plan completion	Total area currently protected by WDNR[1] within plan boundary (km^2, percent of plan area)	Total area currently protected within plan boundary (km^2, percent of plan area)
1939	19,268 (13.3%)	577 (3.0%)	2,255 (11.7%)	11,226 (58.3%)
1964	30,842 (21.2%)	1,495 (4.8%)	3,130 (10.1%)	15,979 (51.8%)
2004	44,229 (30.4%)	3,113 (7.0%)	4,293 (9.7%)	12,754 (28.8%)
2008	37,034 (25.5%)	3,741 (10.1%)	4,469 (12.1%)	14,359 (38.8%)

[1] The Wisconsin Department of Natural Resources (WDNR) is the state natural resources management agency.

Table 8. Importance of factors in explaining variability in implementation of priority areas in the current conservation plan for Wisconsin, USA. Importance values for all metrics in the model sum to 100%. Please see Figure 10 for a schematic of the model, and Table 6 for descriptions of model components and metrics.

Metric	Model component	Importance
Extent protected by WDNR[1]	Support (agency and broad-based)	33.7%
Existing WDNR land protection projects	Agency policy	26.1%
Water	Agency policy	9.8%
Private lands conservation behavior	Support (public)	4.6%
Land use planning	Support (local government)	4.4%
Partner conservation easements	Support (partner)	4.0%
Wetlands	Agency policy	3.1%
Land cost	Final approval	2.5%
Projected housing density	Final approval	2.3%
Endangered resources	Agency policy	2.2%
Land not already protected	Land availability	1.9%
Projected housing growth	Final approval	1.1%

Education	Support (public)	1.0%
Zoning regulations	Support (local government)	0.8%
Political affiliation	Support (public)	0.7%
Forests	Agency policy	0.7%
Population density	Agency policy	0.5%
Income	Support, public	0.4%
Age	Land availability	0.1%
Proximity to cities	Agency policy	0.0%

[1] The Wisconsin Department of Natural Resources (WDNR) is the state natural resources management agency.

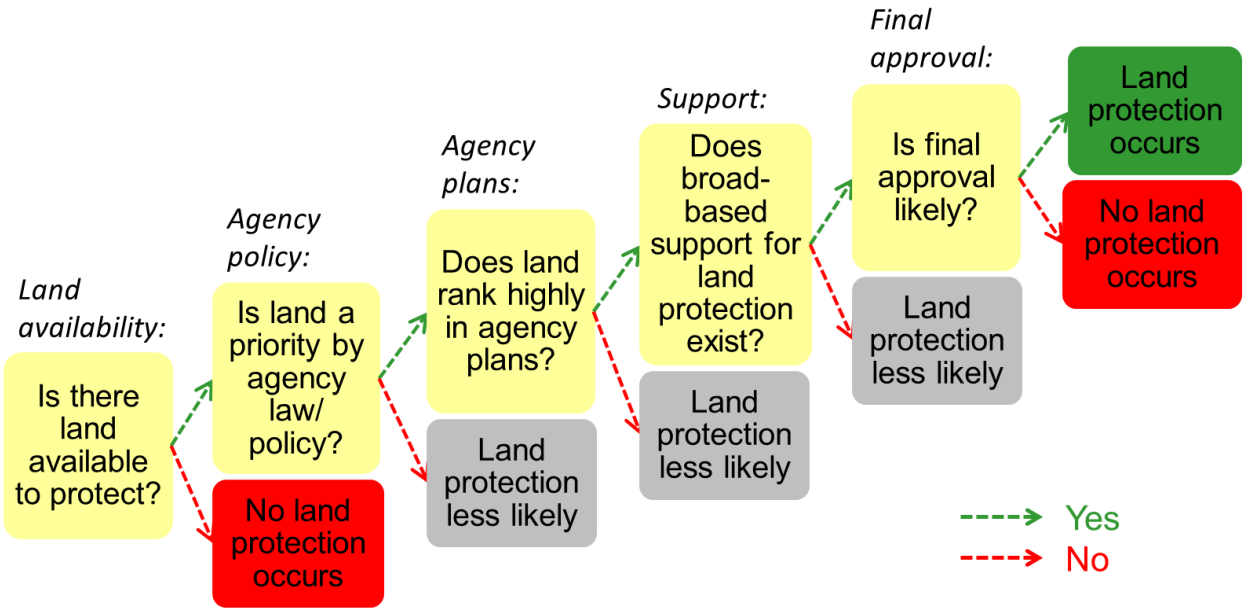

Figure 10. Conceptualization of factors that conservation agencies and organizations consider when seeking to implement actions based on priorities identified in conservation plans. Here we focus specifically on land protection by an agency within the boundaries of an existing plan as the conservation action to be implemented. Dotted green (answer: yes) and red (answer: no) lines indicate next steps when each question is answered.

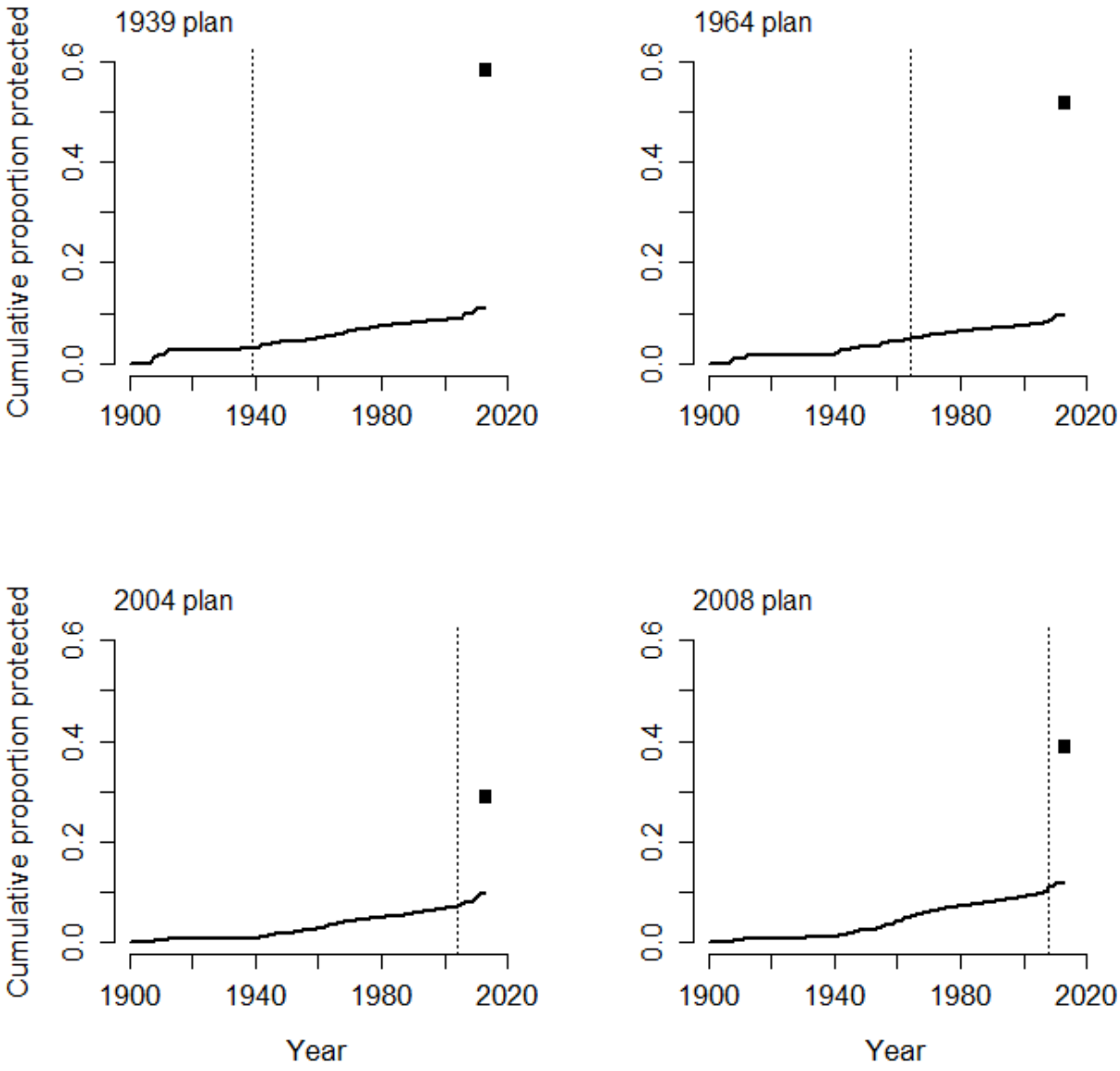

Figure 11. Cumulative proportion of plan area protected over time for four conservation plans developed for the state of Wisconsin. Solid lines represent the cumulative proportion of land inside each plan boundary that was protected by the state land management agency over time. Black squares represent the proportion of the area inside each plan boundary currently protected by all partners combined. Dotted vertical lines indicate the year in which each plan was completed.

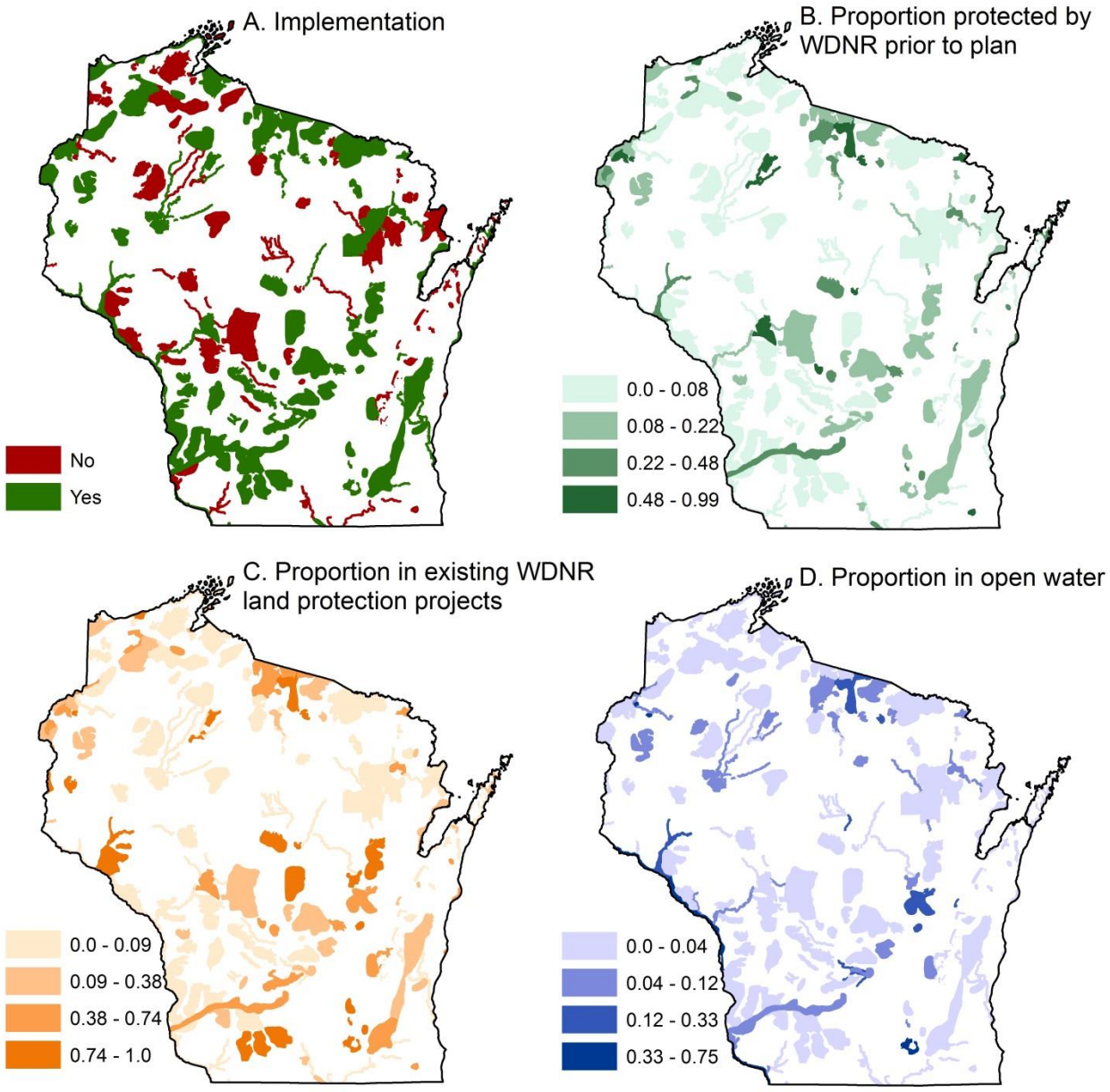

Figure 12. Maps of response (A) and top three explanatory (B-D) variables for priority areas in the 2008 plan. A) Priority areas for which implementation occurred (i.e., land was protected by WDNR within the priority area subsequent to plan completion). B) Proportion of priority areas protected by WDNR prior to plan completion. C) Proportion of priority areas within the boundary of existing WDNR local land protection projects and unprotected. D) Proportion of

priority areas in open water. All explanatory variables are mapped into four classes using natural breakpoints in the data.

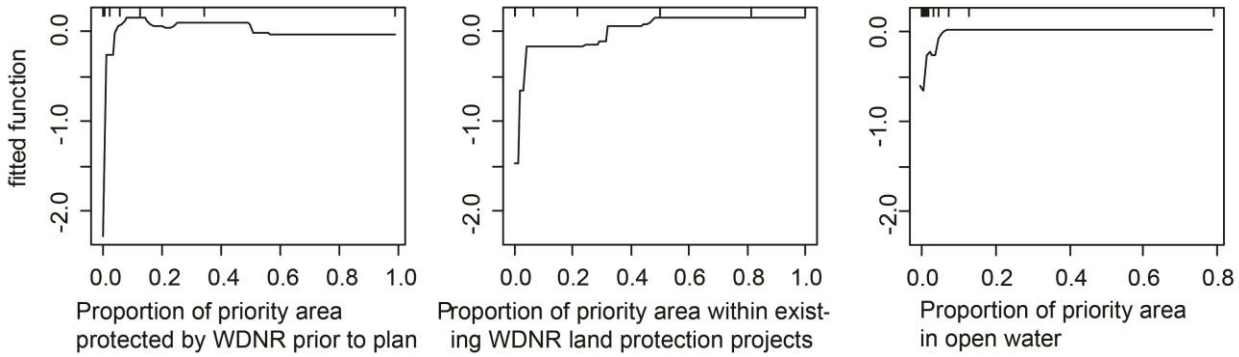

Figure 13. Partial dependence plots for the top three influential variables in the final boosted regression tree model. Percentage values indicate the relative importance of the predictor variable. Rug plots indicate the distribution of values in the dataset.

Appendix A. Administrative rules governing land protection by the Wisconsin Department of Natural Resources.

Rules are current as of October 3, 2014, and may be accessed at http://docs.legis.wisconsin.gov/code/admin_code/nr/001/1.pdf.

NR 1.40 Acquisition of recreational land.

(1) In the acquisition of recreational lands, the department shall place principal emphasis on the acquisition of lands in the heavily populated areas of the state and in places readily accessible to such areas.

(2) Projects under this section will be undertaken based on the following descending order of priority:

(a) Consolidation and completion of existing projects.

(b) New acquisition projects based on the following criteria listed in descending order of priority:

1. Land to protect rare and threatened natural resources; to protect genetic and biological diversity; and to protect, manage or restore critical fish and wildlife habitat.

2. Unique, one-of-a-kind opportunities that may only be available once; projects of special scenic quality; and projects that are "irreplaceable"; an uncommonly large tract of unique natural resources of sufficient size to provide immediate and significant results in meeting program goals.

3. Water-based resources that include land important to protect and improve the quality of the state's surface and ground water; and land for recreation and management along streams, rivers, lakes and flowages.

4. Lands to accommodate broad, natural resource-based outdoor recreation and state recreational trails.

5. Land within 40 miles of Wisconsin's 12 largest cities. If funding limits the ability to purchase available lands within existing urban areas, preference will be given to rural lands near population centers.

Note: Wisconsin's 12 largest cities are: Milwaukee, Madison, Green Bay, Racine, Kenosha, Appleton, West Allis, Waukesha, Eau Claire, Oshkosh, Janesville and LaCrosse.

6. Protection of scenic lands that meet the department priorities in subds. 1. to 5.

(c) Proposed new projects which fall within the following criteria will be given lower priority. Low priorities are not listed in order.

1. Wetland projects acquired primarily to provide additional protection beyond regulation and zoning that do not meet other recreational, water quality or resource management needs.

2. Projects to protect and preserve natural resources not threatened with incompatible use.

3. Projects not part of large, broad-based integrated management efforts to provide multiple outdoor recreational opportunities.

4. Timber production areas that do not meet other recreational, water quality or resource management needs.

5. Lands owned by another unit of government and not threatened with sale or incompatible use.

(3) All new projects shall be subject to natural resources board approval.

History: Cr. Register, April, 1975, No. 232, eff. 5-1-75; r. and recr. (2), Register, February, 1996, No. 482, eff. 3-1-96.

NR 1.41 Land acquisition authorization.

(1) The following land transactions of the department shall require board approval:

(a) Acquisitions where the purchase price is $150,000 or more.

(b) Acquisitions where more than 40 acres are outside of an established project boundary.

(c) Acquisitions where the purchase price exceeds the highest appraised value.

(d) Acquisitions by condemnations of land.

(e) Acquisitions by gifts of land to the department.

(f) Acquisitions where improvement values exceed 35% of total appraised value.

(g) Acquisitions of short tenure with substantial increased value.

(h) Sales of state land that are no longer needed for conservation purposes where the value exceeds $50,000 or where the acreage exceeds 40 acres.

(2) The secretary may approve all other land transactions.

(3) The department shall submit to the board a yearly statistical report on the land control program, including an analysis of the program's status in relationship to the state recreational plan.

(4) The department shall submit to the board at each meeting a report on the status of all options and pending land acquisitions showing the date of each option.

History: Cr. Register, April, 1975, No. 232, eff. 5-1-75; am. Register, April, 1976, No 244, eff. 5-1-76; r. and recr. Register, November, 1985, No. 359, eff. 12-1-85.

Appendix B. Goals, priority area criteria, and priority area descriptions for conservation plans.

1939 plan. The goal of the 1939 plan was to 'provide an adequate and flexible system for the protection, development and use of forests, fish and game, lakes, streams, plant life, flowers, and other outdoor resources in the State of Wisconsin' (Wisconsin State Planning Board and Conservation 1939). Criteria for identifying priority areas included preservation of the native landscape and fauna, size (e.g., goal for state parks to be greater than 1,000 acres), proximity to roads and urban centers (to increase recreational value), marginal soils for agriculture (in the case of state forests), cost, and scenic value (Wisconsin State Planning Board and Conservation 1939). We digitized boundaries for larger priority areas from the published map, boundaries for linear priority areas along river boundaries as a line with a 0.8 km buffer, and boundaries for small priority areas (indicated only with a symbol on the map) as a circle with an area of 0.5 km^2. The resulting 155 priority areas included 17,121 km^2 (11.8% of the state).

1964 plan. The 1964 plan was developed as part of a nationwide effort of the National Park Service with the cooperation of state and local agencies (Service 1964). The goal of the plan was to identify and protect irreplaceable scenic, scientific, and historic resources for future generations (Service. 1964). Areas were chosen based on these criteria and their biological, geological, and physiographical features. We digitized boundaries for larger priority areas from the published map, boundaries for scenic roads and rivers as lines with a 0.8 km buffer, and boundaries for smaller priority areas as a circle with an area equivalent to the project size indicated in the plan (Service 1964). The resulting 204 priority areas included 30,842 km^2 (21.2% of the state).

2004 plan. The goal of 2004 plan was to identify the most important places to meet Wisconsin's conservation and recreation needs over the next 50 years (Pohlman et al. 2006). Priority area criteria included lands and adjacent waters that 1) contain high quality natural areas, important populations of rare species, regionally significant biological or geological resources, or representative species, habitats, and ecological systems across the state, 2) occur near population centers and support, or could be restored to support, native plants and animals and their habitats, 3) ensure that public lands and waters can support their desired recreational uses and habitats, 4) allow the protection of large, minimally-fragmented, ecologically functional landscapes, and 5) establish an interconnected network of corridors that maximize ecological benefits. Additional priority area criteria related to scenic beauty, access to public lands and waters, surface waters, municipal drinking water systems, and recreational opportunities. The final plan identified 230 priority areas, and was approved by the oversight board of the Wisconsin Department of Natural Resources in 2004. The plan identified only the centroids of priority areas, along with a size category for the projected final size of each (small (<5,000 acres (20.2 km^2)), medium (5,000-50,000 acres (20.2 - 202.3 km^2)), or large (> 50,000 acres (202.3 km^2))). We approximated boundaries for lake and riverine priority areas by buffering water bodies by 0.8 km. We approximated boundaries of other priority area as a circle around each centroid with an area of 20.2 km^2, 202.3 km^2, or 404.7 km^2, and excluded portions of circles that fell outside of the state boundary. The resulting priority areas included 44,228 km^2 (30.4% of the state).

2008 plan. Wisconsin's Wildlife Action Plan (henceforth the 2008 plan, (WDNR 2005, 2008) was part of a nationwide effort by the federal government to identify and address the needs of declining wildlife species before they reach the point of possible listing under the federal endangered species law. The 2008 plan included five criteria to identify priority areas: 1) high

priority natural communities and/or concentrations of wildlife 'Species of Greatest Conservation Need' (WDNR 2005), 2) representative and significant ecological features considered Wisconsin's conservation responsibility, 3) priority conservation sites in other plans, 4) areas that establish an interconnected network, and 5) large, minimally-fragmented, ecologically functioning systems. The plan classified the conservation significance of each priority area as statewide, Midwest, national, or global. Terrestrial priority area boundaries for the 2008 plan were available as GIS data; boundaries for lake and aquatic priority areas were created by buffering priority water features by 0.8 km. The final plan identified 255 priority areas covering 37,033 km^2 (25.5% of the state). For analysis of factors influencing implementation of the 2008 plan (Chapter 3), the plan boundaries were modified as follows: we retained only those aquatic priority areas for which 50% or more of the area of the aquatic priority area did not overlap with a terrestrial priority area. This change decreased the number of priority areas to 231, and the area contained within the plan boundary to 36,471 km^2.

Appendix C. Factors associated with changes in land protection actions statewide.

Factors associated with changes in the total value of lands protected statewide (Table 1), total annual area of land protected statewide (Table 2), and total annual number of land protection transactions statewide (Table 3). Asterisks denote partial regression coefficients for plan effects that were significant at the $p<0.05$ level and for which the full model regression explained significantly more variability than the null model.

Table C.1. Factors associated with changes in the total annual value of lands protected statewide[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	6.00	3.58	0.098
1939 plan in place	2.59	0.65	< 0.001*
1964 plan in place	0.34	0.79	0.67
2004 plan in place	-0.12	0.83	0.88
2008 plan in place	0.70	0.88	0.43

Log(US gross domestic product (billions US dollars))	0.80	0.52	0.12
Federal funding to states for land protection (millions US dollars)	0.00047	0.00058	0.42
State funding for land protection (millions US dollars)	0.023	0.018	0.18

[a] response variable is log transformed

[b] Full model: R^2=0.71, F=27.2, df=7 and 76, p-value < 0.001

Table C.2. Factors associated with changes in the total annual area of land protected statewide[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	1.54	7.88	0.84
1939 plan in place	6.09	1.43	< 0.001*
1964 plan in place	-2.16	1.74	0.22
2004 plan in place	1.05	1.84	0.57
2008 plan in place	6.05	1.94	0.002*
Log(US gross domestic product (billions US dollars))	0.11	1.14	0.92
Federal funding to states for land protection (millions US dollars)	-0.00044	0.0013	0.73
State funding for land protection (millions US dollars)	0.079	0.039	0.044*

[a] response variable is square root transformed

[b] Full model: R^2=0.57, F=14.57, df=7 and 76, p-value < 0.001

Table C.3. Factors associated with changes in the total annual number of land protection transactions statewide[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	-31.03	15.12	0.022
1939 plan in place	0.73	1.88	0.35
1964 plan in place	-3.08	1.92	0.056
2004 plan in place	-1.77	1.96	0.18
2008 plan in place	3.59	1.98	0.037*
Log(US gross domestic product (billions US dollars))	5.23	1.91	0.038*
Federal funding to states for land protection (millions US dollars)	-0.0016	0.0012	0.096
State funding for land protection (millions US dollars)	0.010	0.022	0.32

[a] response variable is square root transformed

[b] 1st order autoregressive model

Appendix D. Factors associated with changes in land protection actions occurring inside conservation plan boundaries.

Factors associated with changes in the total annual value of land protected, area of land protected, and number of land protection transactions occurring inside plan boundaries for the 1939 (Tables C.1-C.3), 1964 (Tables C.4-C.6), 2004 (Tables C.7-C.9), and 2008 (Tables C.10-C.12) conservation plans. Asterisks denote partial regression coefficients for plan effects that were significant at the $p<0.05$ level and for which the full model regression explained significantly more variability than the null model.

Table D.1. Factors associated with changes in the total annual value of land protected inside the 1939 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	1.38	13.26	0.92
1939 plan in place	2.37	1.78	0.20
Log(US gross domestic product (billions US dollars))	1.26	1.93	0.52

[a] response variable is log transformed (transformation: log+12.49)

[b] Full model: R^2=0.36, F=7.60, df=2 and 27, p-value=0.002

Table D.2. Factors associated with changes in the total annual area of land protected inside the 1939 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	-0.065	9.76	0.99
1939 plan in place	2.16	1.31	0.11
Log(US gross domestic product (billions US dollars))	0.065	1.42	0.96

[a] response variable is log transformed (transformation: log + 0.0013)

[b] Full model: R^2=0.30, F=5.83, df=2 and 27, p-value=0.008

Table D.3. Factors associated with changes in the total annual number of land protection transactions inside the 1939 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	-6.67	3.18	0.046
1939 plan in place	0.52	0.43	0.23
Log(US gross domestic product (billions US dollars))	1.22	0.46	0.014*

[a] response variable is log transformed (transformation: log + 1)

[b] Full model: R^2=0.68, F=28.82, df=2 and 27, p-value<0.0001

Table D.4. Factors associated with changes in the total annual value of land protected inside the 1964 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	1.06	3.77	0.78
1964 plan in place	-0.43	0.43	0.32
Log(US gross domestic product (billions US dollars))	1.62	0.48	0.002*
Federal funding to states for land protection (millions US dollars)	-0.000017	0.00031	0.96
State funding for land protection (millions US dollars)	0.042	0.012	0.001*

[a] response variable is log transformed

[b] Full model: R^2=0.80, F=34.02, df=4 and 35, p-value<0.0001

Table D.5. Factors associated with changes in the total annual area of land protected inside the 1964 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	2.60	4.31	0.55
1964 plan in place	-0.43	0.49	0.39
Log(US gross domestic product (billions US dollars))	0.07	0.55	0.90
Federal funding to states for land protection (millions US dollars)	-0.00022	0.00035	0.53
State funding for land protection (millions US dollars)	0.022	0.013	0.11

[a] response variable is log transformed

[b] Full model: R^2=0.08, F=0.76, df=4 and 35, p-value=0.56

Table D.6. Factors associated with changes in the total annual number of land protection transactions inside the 1964 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	-2.17	2.80	0.22
1964 plan in place	-0.25	0.25	0.16
Log(US gross domestic product (billions US dollars))	0.75	0.36	0.021*
Federal funding to states for land protection (millions US dollars)	-0.0001	0.0002	0.29
State funding for land protection (millions US dollars)	0.017	0.0067	0.009*

[a] response variable is log transformed

[b] 1st order autoregressive model

Table D.7. Factors associated with changes in the total annual value of land protected inside the 2004 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	15.62	0.40	<0.0001
2004 plan in place	0.56	0.36	0.13
Wisconsin gross domestic product (millions US dollars)	0.0000046	0.0000029	0.12
Federal funding to states for land protection (millions US dollars)	0.00042	0.0020	0.84
State funding for land protection (millions US dollars)	0.00079	0.0093	0.93

[a] response variable is log transformed

[b] Full model: R^2=0.56, F=7.75, df=4 and 24, p-value=0.0004

Table D.8. Factors associated with changes in the total annual area of land protected inside the 2004 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	3.42	0.54	<0.0001
2004 plan in place	0.83	0.49	0.10
Wisconsin gross domestic product (millions US dollars)	0.0000023	0.0000039	0.56
Federal funding to states for land protection (millions US dollars)	0.000074	0.0028	0.98
State funding for land protection (millions US dollars)	-0.0061	0.013	0.63

[a] response variable is log transformed

[b] Full model: R^2=0.35, F=3.24, df=4 and 24, p-value=0.029

Table D.9. Factors associated with changes in the total annual number of land protection transactions inside the 2004 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	5.42	0.18	<0.0001
2004 plan in place	0.36	0.16	0.036
Wisconsin gross domestic product (millions US dollars)	-0.000004	0.0000013	0.012
Federal funding to states for land protection (millions US dollars)	-0.00061	0.00093	0.52
State funding for land protection (millions US dollars)	0.00026	0.0042	0.95

[a] response variable is log transformed

[b] Full model: R^2=0.26, F=2.14, df=4 and 24, p-value=0.11

Table D.10. Factors associated with changes in the total annual value of land protected inside the 2008 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	14.91	0.47	<0.0001
2008 plan in place	2.44	0.44	0.59
Wisconsin gross domestic product (millions US dollars)	0.0000079	0.0000038	0.053
Federal funding to states for land protection (millions US dollars)	-0.0010	0.030	0.74
State funding for land protection (millions US dollars)	0.0076	0.011	0.51

[a] response variable is log transformed

[b] Full model: R^2=0.53, F=5.71, df=4 and 20, p-value=0.003

Table D.11. Factors associated with changes in the total annual area of land protected inside the 2008 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	3.08	0.55	<0.0001
2008 plan in place	0.68	0.51	0.20
Wisconsin gross domestic product (millions US dollars)	0.0000017	0.0000044	0.70
Federal funding to states for land protection (millions US dollars)	0.0012	0.0035	0.72
State funding for land protection (millions US dollars)	0.0066	0.013	0.62

[a] response variable is log transformed

[b] Full model: R^2=0.28, F=1.97, df=4 and 20, p-value=0.14

Table D.12. Factors associated with changes in the total annual number of land protection transactions inside the 2008 plan boundary[a,b]

Coefficients	Estimate	Std. Error	P value
Intercept	5.44	0.16	<0.0001
2008 plan in place	0.57	0.15	0.0013*
Wisconsin gross domestic product (millions US dollars)	-0.000005	0.0000013	0.0013*
Federal funding to states for land protection (millions US dollars)	0.0014	0.0010	0.19
State funding for land protection (millions US dollars)	0.0027	0.0039	0.50

[a] response variable is log transformed

[b] Full model: R^2=0.48, F=4.69, df=4 and 20, p-value=0.008

Appendix E. Land protection activity within individual (local) projects before and after formal project approval.

	Total value of land protected inside project boundary	Total area of land protected inside project boundary	Total number of land protection transactions inside project boundary
Number of projects with majority of activity before project approval	19	31	21
Number of projects with majority of activity after project approval	344	340	342
Number of projects with equal activity before and after project approval	8	0	8
Test results	X^2=291.0, df=1, p<0.001	X^2=257.4, df=1, p<0.001	X^2=283.8, df=1, p<0.001

Appendix F. Mean proportion of total land protection activity occurring inside plan boundaries before and after completion of statewide conservation plans.

	Proportion of the value of land protected occurring inside plan boundary	Proportion of the total area of land protected occurring inside plan boundary	Proportion of the total number of land protection transactions occurring inside plan boundary
1939 plan	before: 0.56	before: 0.70	before: 0.65
	after: 0.36	after: 0.28	after: 0.38
	t=2.03, df=21.1, p=0.06	t=4.92, df=20.7, p<0.001	t=3.28, df=21.8, p=0.003
1964 plan	before: 0.35	before: 0.38	before: 0.39
	after: 0.30	after: 0.36	after: 0.32
	t=1.21, df=28.6, p=0.24	t=0.31, df=28.6, p=0.76	t=2.52, df=33.9, p=0.02
2004 plan	before: 0.61	before: 0.60	before: 0.59
	after: 0.58	after: 0.59	after: 0.63
	t=0.57, df=12.3, p=0.58	t=0.12, df=10.2, p=0.90	t=-2.18, df=18.2, p=0.04
2008 plan	before: 0.53	before: 0.53	before: 0.56

	after: 0.52	after: 0.46	after: 0.57
	t=0.12, df=4.6 p=0.91	t=0.53, df=4.6, p=0.62	t=-0.14, df=4.9, p=0.89