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Incorporating biodiversity conservation and recreational wildlife values into smart growth land use planning

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ABSTRACT

Smart growth land use planning seeks to balance the infrastructure needs of a growing human population and protection for the environment. Unfortunately, the data required to adequately incorporate biodiversity objectives into land use plans is often not available to planners. One problem is that there are few documented methods that detail how biodiversity data held by resource management agencies can be converted to a format useful for inclusion into smart growth plans. Here we demonstrate an approach that allows for state, provincial, or federal resource management agencies to disseminate data on (1) biodiversity conservation, and (2) conservation of wildlife of recreational value for incorporation into local land use plans. Our approach uses modeled threats and species richness data to identify high priority conservation areas and areas more suitable for future development. This approach provides a transparent mechanism to facilitate inclusion of biodiversity objectives into smart growth planning.

1. Introduction

Recently many communities and governments have undertaken initiatives to implement new land use planning practices so that a balance is reached between infrastructure and preservation of natural land, critical environmental areas, and ecosystem services (Daniels, 2001; Downs, 2005; Kaplan et al., 2004). This concept is often referred to as *smart growth* (Daniels, 2001; Downs, 2005; Smart Growth Network, 2008). This approach predicts that the higher quality of life in communities that embrace the smart growth concept will make them more economically competitive and create more business opportunities (Iams and Kaplan, 2006; Preuss and Vemuri, 2004). While the Smart Growth Network has identified preservation and maintenance of the environment and biotic diversity as one of ten guiding smart growth principles, methods to incorporate these values into the land use planning process remain inadequate (Daniels and Lapping, 2005; Miller et al., 2009; Stokes et al., 2010).

Because local governments plan for and decide current and future land use, their role in biodiversity conservation is crucial (Azerrad and Nilon, 2006; Beardsley et al., 2009; Polasky et al., 2008; Press et al., 1996). As county and municipal governments enact zoning and other ordinances, or consider development projects, conservation of biodiversity can be enhanced or impeded (Crist et al., 2000; Miller et al., 2009; Polasky et al., 2008; Theobald et al., 2000). A major obstacle that prevents biodiversity conservation from being adequately incorporated into smart growth planning is insufficient biodiversity data or lack of biodiversity data in an appropriate format (Azerrad and Nilon, 2006; Crist et al., 2000; Miller et al., 2009; Pierce et al., 2005).

Site-specific biodiversity data (e.g., State of Arizona On-line Environmental Review Tool, State of California on-line BIOS system) are often readily available to local land use planners. Such data are not adequate to allow for the inclusion of biodiversity into comprehensive smart growth planning documents such as general plans or regional growth plans because such planning documents require a broader analysis that integrates site-specific species data with threats to biodiversity and couches the analysis in terms of a landscape or regional scale (Crist et al., 2000; Myers et al., 2000). What local planners need is a simplified or coarse measure of importance for biodiversity conservation across the planning area (Crist et al., 2000; Pierce et al., 2005). Incorporating biodiversity conservation during general land use planning efforts is critical to minimizing future growth/conservation conflicts on specific development projects.

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In an attempt to provide the broader scale analyses of biodiversity needed for smart growth and regional land use planning, various organizations and agencies have developed regional or landscape level biodiversity conservation plans (e.g., CFG, 2002; Marshall et al., 2006; Pima County, 2000). However, these plans almost always focus solely on what areas to protect without explicitly identifying the best areas for development. An important tenet of smart growth is to balance growth and conservation. Therefore, plans that do not include development as an end goal have limited utility in land use planning. To adequately implement principles of smart growth, planners need to know not only what areas should be protected but what areas can be developed.

Finally, the call to incorporate biodiversity conservation into land use planning extends beyond smart growth planning. Over the last decade, the issue of incorporating land use planning and biodiversity conservation has been a focus in conservation biology (Ewing et al., 2005; Groves et al., 2002; Michalak and Lerner, 2007; Theobald et al., 2000). As a result, a variety of conservation groups (Ewing et al., 2005; Groves et al., 2002; Michalak and Lerner, 2007) have proposed some generic methods to integrate land use planning and biodiversity conservation. One key recommendation of these methods is that state or federal agencies assist regional and local governments with the mapping of natural resources and setting priorities for protection (Ewing et al., 2005; Michalak and Lerner, 2007). In this study we document an approach by which state, provincial, or national agencies can provide the simple tools needed by land use planners and decision makers to incorporate biodiversity conservation into smart growth or other types of broad land-use planning. The method described details a flexible framework in which components can easily be modified. Additionally, the same analysis can be conducted on multiple scales (state, region, ecoregion, county, jurisdiction, etc.) after the initial input layers have been created, providing a variety of unique end products for the user.

2. Materials and methods

We use the state of Arizona as a case study to illustrate our methods. To identity areas of high priority for biodiversity and wildlife conservation we relied on data reflecting both threats to biodiversity and species richness (Myers et al., 2000). In addition, because resource management agencies often administer the sometimes contradictory goals of biodiversity conservation and the recreational use of wildlife we have integrated both in this method (Rauschmayer et al., 2008). Although our example spans an entire state, the same methods and inputs described can be used on a more localized scale (county, jurisdiction, ecoregion, etc.).

To provide a simple tool that allows for the incorporation of biodiversity conservation into smart growth planning, we identified areas of importance for species of greatest conservation need and key areas for species important to exploitative (i.e., hunting and fishing) activities. We then included data on threats (e.g., pesticides, mining, fragmentation by roads) to biodiversity in our model. Finally, we synthesized the combination of threats and metrics of biological diversity in order to prioritize areas for conservation and future development (as described below).

2.1. Data

We first identified a set of priority species for management to serve as a surrogate for biodiversity and wildlife conservation in the planning process. Some species were selected because they were a priority for biodiversity conservation and others were selected because they are important recreational wildlife.

Table 1
Categories for species of greatest conservation need (SGCN).

Tier	Criteria
a	Is listed under the federal Endangered Species Act: endangered, threatened, or candidate species Has a signed conservation agreement Requires monitoring as a result of delisting from the Engendered Species Act
b	Is petitioned for listing under the federal Endangered Species Act Is high priority for partner entities as identified in the following lists: Arizona Partners in Flight Bird Conservation Plan, Bureau of Land Management Sensitive Species, US Forest Service Sensitive Species, National Parks Service Sensitive Species, Pima County Priority Vulnerable Species, Trilateral Committee Species of Common Concern, Federal Species of Concern, and Wildlife of Special Concern in Arizona
c	Scored high for vulnerability (see CWCS; AGFD, 2006), but match none of the above criteria

Table 2
Categories for wildlife of recreational importance.

Tier	Criteria
a	Species is a strict habitat specialist-restricted to one to few habitat types Range of species restricted to less than 10% of the state Habitat occupied by species is vulnerable to alteration Species occurs in low abundance
b	Species is a moderate habitat specialist-restricted to few to several habitat types Range of species restricted to less than 50% of the state Species occurs in moderate abundance
c	Recreationally important, but match none of the above criteria

To represent biodiversity conservation, we identified 101 avian species, 61 mammalian species, 49 reptile species, 35 fish species, 30 crustaceans and mollusks, and 17 amphibian species found in Arizona. All species were identified in Arizona's comprehensive wildlife conservation strategy (CWCS) as species of greatest conservation need (SGCN) in the state (AGFD, 2006). Species were identified as being of greatest conservation need for several reasons including: rarity, imperilment, endemism to Arizona, and function in the ecosystem. We further categorized these species into three tiers (Table 1) according to their level of management priority.

To ensure representation of recreational wildlife values we identified a second suite of species important for recreational use in the state. These species include 10 mammals and 6 birds that were further categorized into three tiers based on their degree of habitat specificity, range, abundance, and vulnerability of their habitat to alteration (Table 2). We also incorporated angler use data associated with lakes and rivers as a proxy for areas important for aquatic species of recreational value.

To represent each species in the planning process we used predicted distributions. Because of the uncertainty (spatial, temporal, and taxonomical biases) associated with species occurrence data, predicted distribution models based on parameters deemed necessary for species survival have been developed (Rodriguez et al., 2007; Rondinini et al., 2006; Wilson et al., 2005). To map predicted distributions we used expert-based habitat suitability classifications (Boykin et al., 2007). The predicted distribution for a species was identified as the areas where all required attributes (land-cover type [e.g., vegetation community], elevation, slope, soils, and ecoregion units) co-occurred. For each species, we used the literature and species experts to identify the appropriate range of each attribute. The predicted distribution was further restricted to only those 8-digit hydrological units which the species was known to inhabit based on occurrence records. Combining predicted distribution data with occurrence records has been shown to reduce uncertainty in the conservation planning process (Underwood et al., 2010). Models were created in a raster format with a resolution of

30 m × 30 m pixels. All data were projected in NAD 1983 geographic projection. We chose to use this combination of predicted distribution and occurrence data over species observation data alone to incorporate uncertainty about the actual distribution of the species within the state. Recreational fishing was incorporated into the model by calculating the percentage of total possible angler use days associated with each body of water.

To incorporate threats to wildlife into the planning process we evaluated 71 threats to biodiversity that were identified in the state's CWCS (AGFD, 2006). A detailed description of each threat and how it impacts wildlife is documented in the state's CWCS (AGFD, 2006). Threats ranged from projected urban and rural growth, to the loss of keystone species. For modeling purposes, a number of the originally identified threats were expected to have similar effects on biodiversity or to co-occur spatially on the landscape and therefore were combined. An example would be modeling the "water diversion" and "altered river flow regimes" threats as one contiguous threat affecting waterways (a detailed description of the data and methods used to model each threat can be found at http://www.azgfd.gov/w_c/documents/ThreatMappingReportDraft.pdf). In addition, we considered a select few threats such as "unauthorized roads and trails" to be ubiquitous or data-deficient, and were not modeled. As a result, we reduced the number of threats modeled to 44. Each threat was modeled in a raster format. All threat rasters were rescaled so that the value of any given cell for a particular threat ranged from 0 to 1. Some threats were modeled simply as presence/absence, thus cell values in the raster would score a 0 or 1. Other threats were modeled as gradients such that the areas most affected by the threat would receive a value of 1 and areas less impacted would receive progressively smaller values until areas of no impact were reached that received a 0.

2.2. Populating the model: species richness

The species richness portion of our model was constructed by additively combining summary rasters for our three surrogate groups: SGCN species, terrestrial recreationally important species, and aquatic recreationally important species. Constructing a summary raster for the SCGN surrogate group required four general steps: (1) first, we categorized each species by taxon and then by the three management priority tiers (Table 1; a–c). Working with the species found only in a single tier at a time, we assigned presence/absence for each species to all grid cells in the planning area. If any portion of a species' predicted range was in the cell then the species was considered to be present. (2) We then summed the number of species for a tier found in each cell and divided it by the total number of species (tiers a–c) in that taxon; producing an intermediate raster. After developing an intermediate raster for each tier within a taxon in this manner, (3) we assigned weights to each intermediate raster. We weighted values from the tier a and b intermediate rasters, three and two times more important than values in the tier c intermediate raster. The final step (4) was to additively sum the weighted intermediate rasters for all taxa to produce the SCGN summary raster. A cell in the SCGN summary raster with a high score would signify that an area was highly diverse, or had a large number of species of high management priority. For the terrestrial recreational wildlife we followed a similar process but did not separate the species by taxon as only 16 species comprised this surrogate group.

We used the angler use data (the number of fishing days documented by seasonal angler surveys) associated with all aquatic areas (any area of permanent water in which fishing occurs: lakes, rivers, streams, ponds) to serve as a surrogate for commercially and recreationally important aquatic species. After assigning the number of fishing days to each aquatic area, the value of each aquatic area was normalized by dividing the angler use days associated with the aquatic area by the maximum number of angler use days associated with any aquatic area.

After the three summary rasters (SGCN, terrestrial, aquatic) were produced, we additively combined them into a single richness raster. Each summary raster received equal weight in our final richness raster. In addition, to explore the sensitivity of the final richness raster we alternately weighted each summary raster as three and two times more important than the other components.

2.3. Populating the model: threats

The use of expert opinion to weight threats is a common practice in biodiversity conservation, especially when little quantitative data exist on the threats (e.g., Halpern et al., 2007; TNC, 2000). Our method (outlined below) represents a derivation of commonly applied methods. We weighted threats because all the threats we identified do not have the same type or magnitude of impact on biodiversity or wildlife important for recreation use. To weight the threats we selected a group of 46 professional wildlife and aquatic species experts from all regions of the state. The state is divided into six geographically defined regions and participants were selected so that each region would be equally represented. In addition, a single statewide taxon specific expert was selected for each taxa. Once the group was selected, each participant was given 1000 points and was asked to assign points to all 44 threats, with those threats being the most detrimental for wildlife/biodiversity receiving the greatest number of points. After all participants had completed the weighting, the total number of points assigned to each threat by the group was divided by the total number of points possible (46,000). The percentage derived was then used as the weight for a threat when calculating the final threats raster (0.63–10.28). To produce the final threats raster, for each cell we summed the scores of the weighted threats present. Areas with a high final threat score could either have many threats or be impacted by those threats that were weighted the highest. For mapping purposes, we mapped areas with a high threat score as the areas with greatest stress. We define stress as the summed impact of all threats on biodiversity.

2.4. Final model analysis and application

After we obtained a final richness raster and the final threats stress raster we categorized the landscape of Arizona using a combination of richness values and the stress to biological diversity associated with each area. For land use planning purposes we subdivided the continuum of values that we identified from our final analysis into planning zones (Fig. 1). We identified 16 planning zones based on natural breaks in the values. We further aggregated these 16 zones into four broad zoning types. These four broad zoning types provide a simple tool for planners that allows for the consideration of biodiversity and recreationally important wildlife in the smart growth planning process. Areas categorized as high in species richness and low in stress are areas where development should be avoided. The next most important zone for biodiversity conservation efforts would be areas high in diversity but also high in stress. These two zones would include the areas most commonly identified as important for meeting conservation objectives. By classifying the remaining landscape, we are able to more clearly identify the areas suitable for development from a conservation standpoint. Areas low in diversity and low in stress would be areas in which some development could occur and areas low in diversity and high in stress would be identified as the optimal areas for development projects. Planners could use the aggregated classification scheme or the more explicit 16 planning zones when identifying the best locations for future development. If the 16 planning zones are used, then the lower the score (e.g., 1 or 2) the more

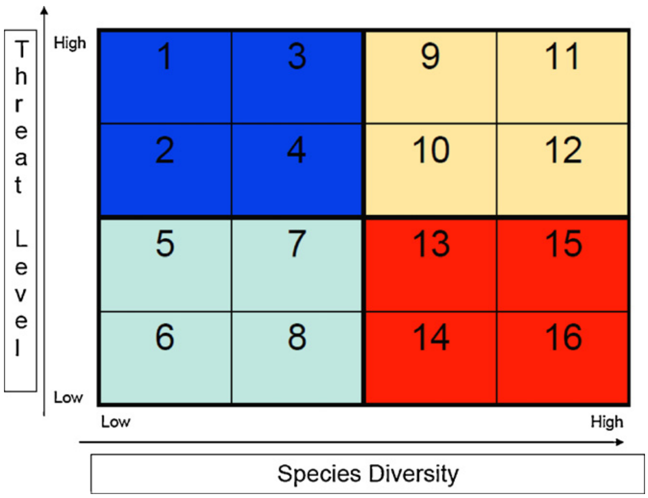

Fig. 1. Land use planning categories based on natural breaks following our summary conservation analysis (richness and threats). The 16 individual categories are further aggregated into four coarse land use planning categories for use when considering biodiversity and recreationally important wildlife in smart growth planning or other regional planning efforts.

suitable for development an area would be deemed. By identifying the areas that would have the least impact on the conservation of biodiversity, we minimize future conflicts between biodiversity conservation and development. However, simply because an area would be appropriate for development from a biodiversity conservation perspective, these areas may not be developable due to engineering constraints or conflicts with other planning priorities.

3. Results

Results include the various component layers as well a final map that synthesizes the parts. Richness layers for biodiversity did not identify markedly different areas of the state as important. Unweighted richness for biodiversity was concentrated in southeastern and central Arizona (Fig. 2). When we weighted this layer, as described in the methods, the areas identified as high in richness remained similar (Fig. 2). However, for terrestrial species of high recreational or commercial value, the areas identified as having highest richness were more dispersed around the state (Fig. 3). The areas of greatest importance for aquatic species of recreation importance were those close to population centers. Threats occurred across the landscape but the areas most stressed tended to be associated with current population centers (Fig. 4).

To create the final tool that allows for the conservation of biodiversity and recreationally important wildlife to be considered in smart growth planning, we combined stress and richness and categorized the results (Fig. 5). Areas of importance for future growth were most often located near current population centers. However, areas for potential future development were distributed across the state. The areas most important for conservation roughly paralleled the locations of high species richness. While most areas in close proximity to current population centers were identified as focus areas for development, there were still high priority areas for conservation that abut current population centers. This was particularly true in the southeastern portion of the state.

When we modified the weighting of the component layers for the final richness raster, we found that the higher the weighting the more the final richness raster tended to mimic the highest weighted layer. However, when we combined these alternately weighted richness rasters with the final threats stress raster to produce our final analysis layer, we found minimal difference in which areas were identified as belonging to each of the four broad zoning types.

4. Discussion and conclusions

The method we have described is intended to help resource management agencies provide local planners with important information they need to incorporate biodiversity conservation into regional or other broad-scale smart growth planning. As we mentioned earlier, conservation planning for biodiversity is not a novel concept. However, to be most useful in land use plan-

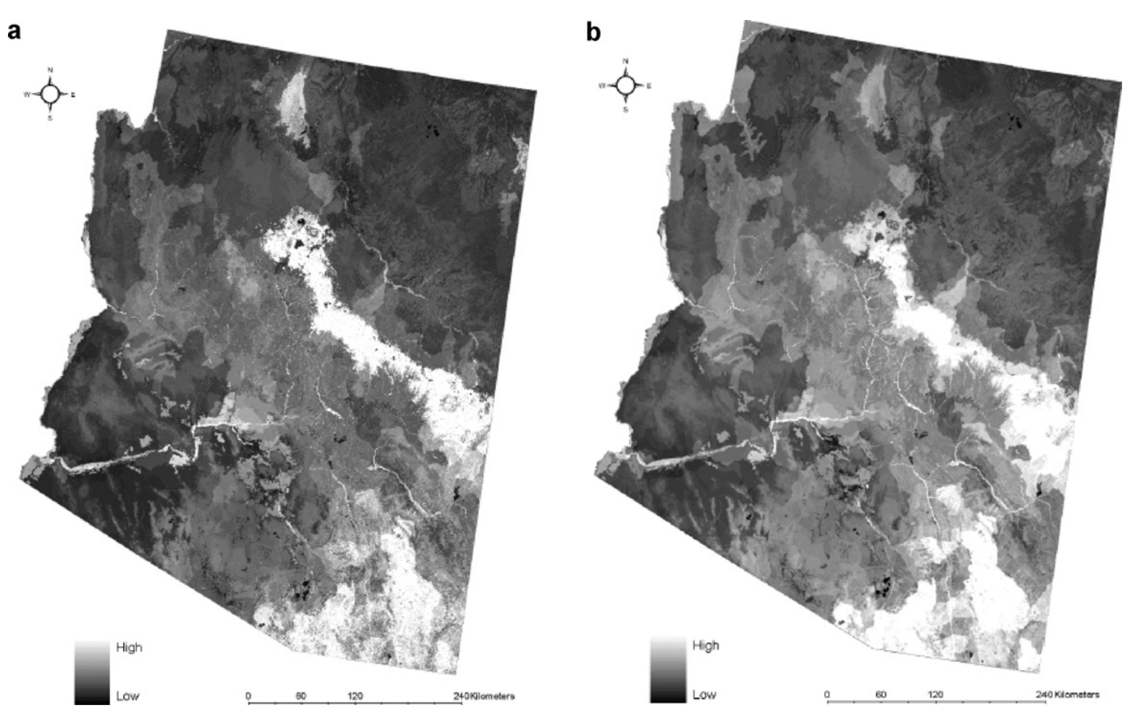

Fig. 2. Unweighted and weighted richness maps for species of greatest conservation need in Arizona, USA. Species weighting scheme as described in the text. (a) Unweighted and (b) weighted.

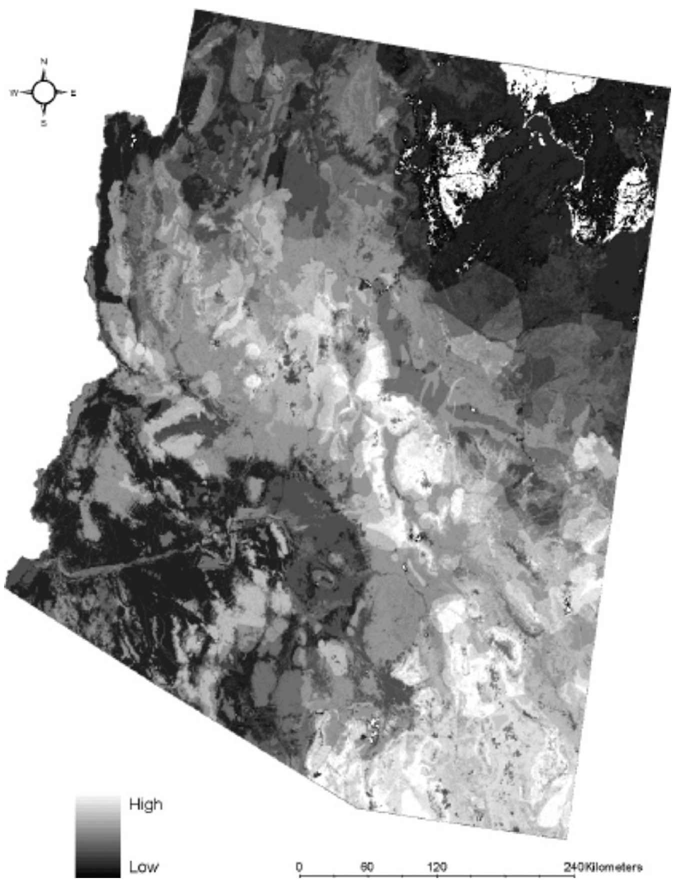

Fig. 3. Richness map for species of recreational importance in Arizona, USA.

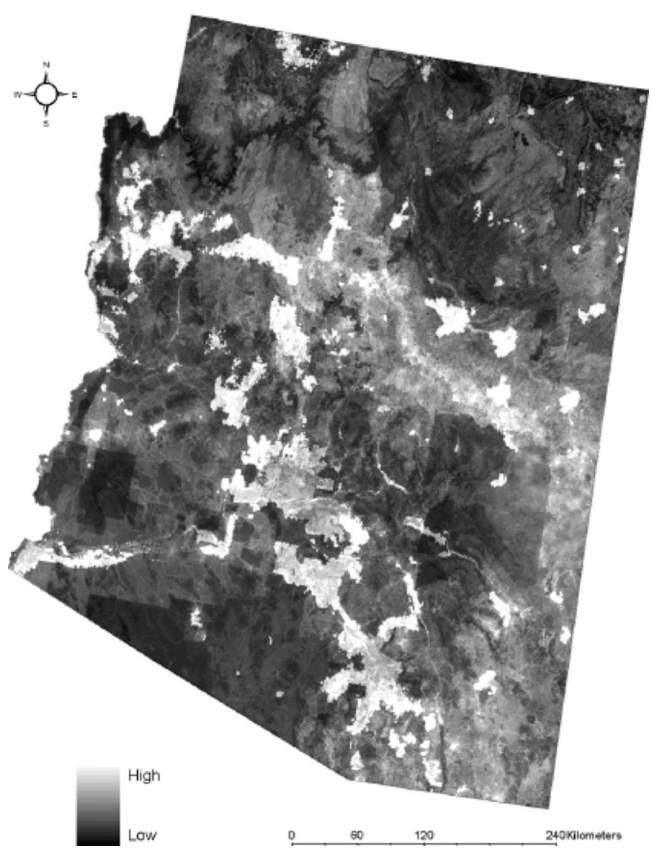

Fig. 4. Map detailing the degree of stress to biodiversity in Arizona, USA.

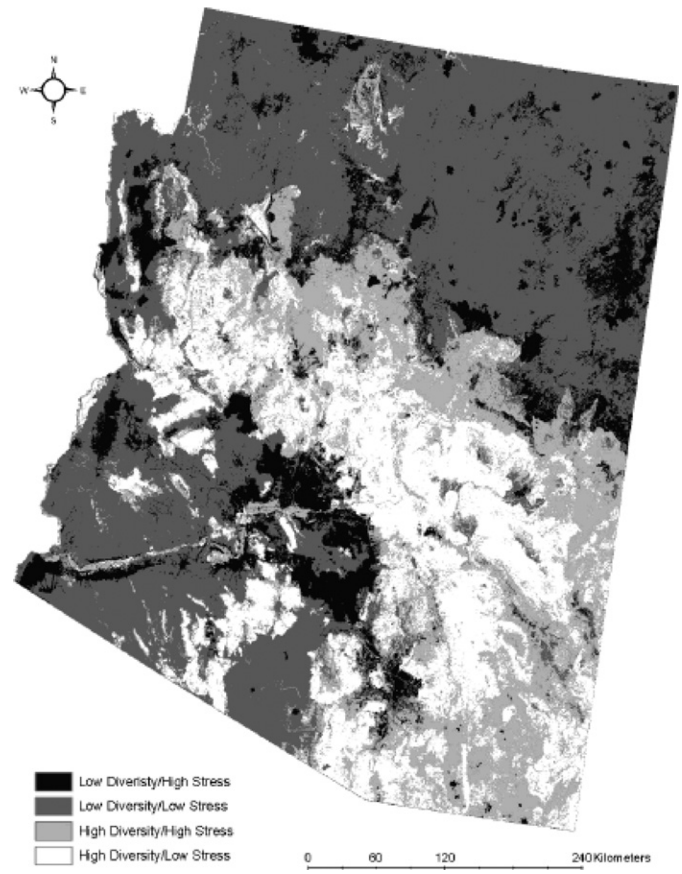

Fig. 5. Final planning tool that identifies the four category classification scheme for use when considering biodiversity and recreationally important wildlife in smart growth planning or other regional planning efforts, Arizona, USA.

ning, biodiversity planning efforts should not only identity areas for conservation but the areas appropriate for development. In attempting to foster smart growth planning, other state resource agencies have developed tools to identify areas of conservation importance for biodiversity and guide future growth. Examples include, Maryland's Green Infrastructure Assessment (Weber et al., 2006), Washington Department of Fish and Wildlife Local Habitat Assessment Program (Carleton and Jacobson, 2009), and Montana's Crucial Areas Assessment and Planning System (Montana Fish Wildlife and Parks, 2010). The methods employed generally use similar input layers (e.g., species distribution, threats, and habitat) to identify areas that are important for conservation. However, few have attempted to include more than one or two threats in their models and almost all fail to explicitly identify the best areas for development. The fact that our approach more comprehensively addresses threats to biodiversity and takes the final step of identifying areas where development should be focused distinguishes it from other state planning efforts and potentially makes it more useful to local conservation planners.

4.1. Scaling

While a statewide measure of importance of can be a useful tool, land use planners often require an analysis that is focused solely on their specific planning area. The same final richness and threats stress rasters produced by this method can be used to supply local planners with an analysis specific to their planning area. Planners can determine a scale that is most appropriate for meeting their environmental goals. This could be a watershed, ecoregion, county, or statewide scale. The analysis can then be conducted on that scale using the methods we have outlined. Rescaling is accomplished by limiting the boundary of the analysis to the appropriate planning area and then categorizing the results based solely on the combination of biological richness and stress values within that specific area. Such an analysis provides a set of planning zones and broad zoning types that are unique to the planning area and relative only to other locations within the planning area. With both a statewide and local analysis, planners have an understanding of the statewide importance of their planning area for biodiversity conservation, and a more localized analysis of the relative importance of each location within their specific planning area. This combination provides planners with a framework from which they can make decisions.

Smaller scale analyses can significantly alter which areas are identified for conservation/development (Andelman and Willig, 2002; Shriner et al., 2006; Warman et al., 2004;). As an example, under our statewide analysis, almost all areas in Cochise County (southeastern Arizona) are considered to be high in diversity and therefore would be identified for little or no development. However, when our same analysis was limited only to Cochise County, the differences in richness and threat within the county caused some areas to be identified as low in diversity and therefore more amenable for development. This result represents a common challenge encountered in both conservation and land use planning, outcomes can be highly scale dependent (Andelman and Willig, 2002; Shriner et al., 2006; Warman et al., 2004). Because of the scale dependency inherent to the results, it is important that land use plans consider biodiversity conservation on a scale that will not prohibit the long-term viability of biodiversity.

4.2. Possible alterations

In this study we found that weighting and combining biological diversity and recreationally important wildlife components produced a final result similar to uncombined or unweighted products. However, if different species, threats, scales, or locations were considered, weighting or combining might produce results that differ drastically from their unweighted or uncombined components. This does not invalidate our approach as the goal was to produce a flexible framework that can be easily adapted by planners depending on goals and objectives. Weights for each of the input layers, choice of surrogate species, or the normalization of species richness data by taxon, could all be altered to meet a planner's goals.

For example, one of our goals was for each taxa to have a similar weight in our analysis regardless of the total number of species in each taxa. To accomplish this goal we normalized the richness results for each taxa as described in the methods. If we had used straight species richness as a metric, owing to the large number of species, avian richness would have driven the model. If planners desire that each species receive equal weight, then no normalization would be required.

Another goal was to ensure that species with a legal mandate for conservation received the greatest level of protection. To achieve this goal, we divided the species into tiers (see Tables 1 and 2), and assigned different weights to the tiers to ensure that areas containing species with a legal mandate for conservation received higher weight. The weighting of species could be altered to focus conservation on different groups or be eliminated.

We used only harvestable species as a surrogate for recreational wildlife in our model. However, by some estimates hunting generates only a fraction of the economic benefits in comparison to other pertinent recreational uses, such as bird watching. Passive recreational activities such as bird watching can contribute millions of dollars to local economies (Leones and Colby, 1998). Unfortunately, very little of such passive recreational money funds state, provincial, or national wildlife agencies who are for the most part the legal caretakers of biodiversity. That said, one could expand the recreational wildlife surrogate group to include species that are important for passive recreational activities to develop a more inclusive representation of recreationally important wildlife.

4.3. Prioritization for conservation

A lively debate among members of our working group arose when we were required to decide which planning zone should be identified as the highest priority for conservation. The debate centered on whether the areas high in diversity and high in stress or the areas high in diversity and low in stress should receive the highest priority for conservation. In the end we choose to designate the areas identified as high in diversity and low in stress as the top priorities. However, unanimous consensus on this decision was never reached.

The rationale for our choice is based on the assumptions that lands with a low level of threat cost less for long-term management, that lands in both categories carry equal conservation significance, and that a predetermined amount of money exists for conservation. As an example, if you had two parcels of land in the same vegetation community that were both equally diverse and could be purchased for a similar price, but one was plagued with numerous threats it would likely cost more money in the long-term to reduce/manage the threats to the parcel of land with the higher level of threat. The benefit to choosing the parcel of land with a low level of stress is that the monies you would have spent on management of a highly threatened parcel could then be used to acquire and manage additional lands, resulting in the net conservation of more land.

The argument for an opposite prioritization strategy is centered on the assumption that areas with low stress will remain in that state. If this is true, then the majority of conservation dollars spent should be for acquisition and management of areas currently facing the greatest level of threat. Once those areas are protected, then protection of less threatened areas can commence. Ultimately, the assumptions associated with both arguments are probably somewhat unrealistic/simplistic and actual implementation of the conservation strategy will likely require a case by case analysis of each parcel considered for acquisition. Thus, it is probably essential to consider all areas high in diversity (regardless of level of stress) for conservation.

4.4. Comprehensive biodiversity conservation planning

The methods we have described provide only some of the components required to comprehensively consider biodiversity when land use planning. In addition to the products of this method, to comprehensively consider biodiversity in land use planning the following items should be addressed when possible.

First, this method does not ensure that the areas identified for protection adequately represent all types of biodiversity, wildlife of priority for conservation, or recreationally important wildlife. A follow-up conservation analysis would be needed to ensure that representation of all species of concern occurs in the areas identified as least desirable for development. Alternatively, the use of systematic reserve design instead of species richness could be used as a method for ensuring that all facets of biodiversity are represented in the areas identified for conservation priority (Margules and Pressey, 2000). However, systematic conservation planning can require the use of specific GIS applications that require time to learn, whereas the methods we have described make use of common GIS functions.

Second, conservation plans and associated maps of priorities are static by nature and therefore do not adequately address temporal issues. We suggest that products created according to these methods be reviewed and updated if necessary on a regular basis. In the state of Arizona such a review is conducted every five years.

Third, when modeling threats each threat was assumed to have a similar impact on all species. In actuality this is highly unlikely as different species respond to different threats in a variety of manners. We tried to account for some of this variability by selecting different taxon specific experts to weight the threats. Each expert weighted threats according to the impact on their taxa of concern. However, it would be better to incorporate data on how each threat specifically affects each species of concern. To accomplish such an analysis would require a tremendous effort that would likely be time and cost prohibitive.

Fourth, this model does not include data created to address the connectivity required to maintain biodiversity across the landscape. To more fully include biodiversity conservation in smart growth planning, a planning effort should consider how to maintain connectivity across the natural landscape. In Arizona, a connectivity analysis has been conducted for the state and areas have been identified that are important for connectivity (Nordhaugen et al., 2006).

Finally, the products generally do not contain the level of specificity required to make decisions within a particular parcel. As particular locations are developed, site-specific biodiversity information is needed (Crist et al., 2000; Miller et al., 2009). Site-specific data is necessary to determine a precise footprint for development so that impacts to biodiversity on the site are minimized. When site-specific biodiversity data are not considered, irreplaceable biological resources may be impacted compromising the future of biodiversity in an area and resulting in failure to meet the guiding tenets of successful smart growth. While not designed to function on the site-specific level, products of the method described herein can assist planners in project level analyses. For example, input layers (e.g., predicted species distributions) can be used to identify which species of importance may occur on a parcel. However, a site-specific review of the biological resources would still be required.

4.5. Conclusion

In this paper we have documented a method that could be used by state, provincial, or national resource management agencies to disseminate biodiversity data in a format that can be easily incorporated into local smart growth plans. Simple tools that provide biodiversity data to local jurisdictions are important because resource management agencies often do not have the manpower to work with every local planning body to ensure that biological diversity conservation is incorporated in land use plans. Our method can also provide planners with more explicit information on where development should be located to have the least impact on biodiversity, this is an important piece of information they are not often provided. However, planning for conservation is just one of the many facets that local land use planners must consider. Planners are often required to balance environmental conservation (biodiversity conservation, conservation of agricultural/forestry uses, maintenance of ecosystem services and water quality) with the potentially competing goals of affordable housing, transportation, fire protection, and other regional or local priorities (Crist et al., 2000; Pierce et al., 2005). The creation of simple tools that can incorporate biodiversity data into coarse-scale land use planning efforts is critical to ensure that environmental values are adequately integrated. The simple products we have described are intended to assist planners by helping them to identify future growth boundaries, areas were clustering of development would be beneficial, the location of green/open space networks, and to help local jurisdictions focus acquisition, easement, and offset programs to the most important areas for biodiversity conservation. Our approach provides a framework that can be adapted to different scales and can be modified to ensure specific management objectives are met.

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