



Conservation planning and assessment of irreplaceability and vulnerability of conservation sites in the ‘Heart of the West’ region, Middle Rockies

Allison L. Jones, Katherine Daly, Erik Molvar and James Catlin

Allison L. Jones

Wild Utah Project
68 South Main Street
Salt Lake City, UT 84101
Phone: (801) 328-3550
Fax: (801) 524-0110
allison@wildutahproject.org

Katherine Daly

Wildlands Project
P.O. Box 455
Richmond, VT 05477
Phone: (802) 434-4077
Fax: (802) 884-0962
kathydaly99@hotmail.com

Erik Molvar

Biodiversity Conservation Alliance
P.O. Box 1512
Laramie, WY 82073
Phone: (307) 742-7978
Fax: (307) 742-7989 FAX
erik@voiceforthewild.org

James Catlin

Wild Utah Project
68 South Main Street
Salt Lake City, UT 84101
Phone: (801) 328-3550
Fax: (801) 524-0110
jim@wildutahproject.org

ABSTRACT: We conducted a Geographic Information System (GIS) conservation assessment of the “Heart of the West” region, which incorporates the Wyoming Basins Ecoregion. This systematic assessment utilized three widely accepted tracks of conservation planning: representing habitat variation across the landscape, incorporating special elements, and securing important habitat for focal species (Noss 2003). Only 4.1% of our study area is currently in some form of protective federal status (i.e. GAP 1 or 2 status lands), and even these holdings fall short of protecting much of the biological diversity of the study area or representing all vegetative communities. Using a simulated annealing site-selection algorithm, and with static focal species habitat models and special element data (i.e. Natural Heritage species locations) as inputs, we used quantitative conservation targets to identify unprotected areas (or proposed core areas) within the region. If these core areas are protected as a conservation network, it will serve to meet various goals such as: restoring viable populations of native plants and animals; protecting sufficient amounts of all habitat types from further degradation and loss; reducing habitat fragmentation and restoring functional connectivity; and protecting and restoring ecological and evolutionary processes. The final proposed network included a total of 8,387,190 ha (or 44.9 % of the study area) in the conservation network portfolio, which included all existing protected areas. We conducted an irreplaceability and vulnerability analysis of 28 large core areas in the proposed conservation network, based on six criteria relating to quantitative conservation goals. This analysis will aid decision-makers by identifying those sites that will contribute most to explicit conservation goals.

Keywords: Conservation Planning, Wyoming Basins, Irreplaceability, Vulnerability, SITES

INTRODUCTION

The past few decades have seen a marked increase in the number of systematic, large-scale conservation planning endeavors meant to identify new reserves (Bennett and Wit 2001, Noss et al. 2002, Groves 2003, Redford et al. 2003). Planning that is systematic in nature (i.e. the use of defined planning units, explicit goals and reserve selection algorithms) may be preferable to more traditional methods that tend to be more opportunistic and biased in nature, and can result in a sub-optimal placement of reserves for promoting long-term maintenance of biodiversity (Margules and Pressey 2000, Scott et al. 2001). Among the key elements of systematic conservation planning are explicit goals and objectives, quantitative and substantiated conservation targets, well-documented and replicable methods, rigorous peer review, and strong criteria for implementation (Noss 2003).

The Wyoming Basins Ecoregion (Bailey 1995 as modified by The Nature Conservancy 2001a), with connections to both the Utah High Plateaus Ecoregion and Southern Rockies Ecoregion, represents a region that is currently not receiving adequate conservation attention (Freilich et al. 2001). While many conservation organizations and initiatives are focused on the greater Yellowstone Ecosystem to the north and the Colorado Rockies to the south, this area in between has a lower conservation profile and is increasingly suffering impacts from America's recent push for large-scale fossil fuel development. Much of the region is open for this use, as only 4.1% of our study area is currently in some form of protective federal status (i.e. GAP 1 or 2 status lands). Although the Wyoming Basins Ecoregion does not support an exceptionally high diversity of species and is thus not considered to be a "hotspot" on a continental or global level, it does represent not only an opportunity to conserve a still relatively intact temperate ecosystem, but is also perhaps the most important stronghold for sagebrush steppe species, including rare and declining species such as sage grouse (*Centrocercus urophasianus*), white-tailed prairie dog (*Cynomys*

leucurus), black-footed ferret (*Mustela nigripes*), and burrowing owl (*Athene cunicularia*).

We carried out a conservation assessment of this region, which, combined with adjacent habitats in the Utah High Plateaus Ecoregion and Southern Rockies Ecoregion, we refer to as the "Heart of the West" study area. Our assessment drew upon four conservation goals that have become commonplace with large scale conservation planning (Noss and Cooperrider 1994): (1) viable populations of all native plants and animals (including some that have been extirpated) are protected and restored; (2) sufficient amounts of all habitat types protected from further degradation and loss; (3) ecological and evolutionary processes are protected and restored, and (4) land is protected from further fragmentation so that functional connectivity can be restored, resulting in a conservation network that is more resilient to environmental change.

In order to achieve these goals in our final product (a conservation network), we incorporate three accepted approaches to developing a conservation assessment (Noss et al. 1999, Foreman et al 2003, Miller et al. 2003, Rumsey et al. 2003): (1) representation of all land cover, or vegetative community, types within a network of core areas (Groves et al. 2000, Groves 2003); (2) identification and protection of special elements such as rare species occurrences (Noss and Coopeerrider 1994, Groves et al. 2000); and (3) protection and linking of key habitat of focal species that serve critical ecosystem roles and/or whose presence is indicative of healthy, functioning systems (Miller et al. 1998, Soulé and Terborgh 1999). We chose this three-track approach because there are weaknesses inherent in each of the three methods (e.g. focal species analyses, see Bonn et al. 2002, Lindenmayer et al. 2002), and relying on only one or two of these approaches may not provide sufficient protection for a large region (Noss et al. 2002, Carroll et al. 2003, Noss 2003). Together, the three tracks of representation analysis, special element mapping, and focal species analysis offer a comprehensive and effective approach to conservation planning.

We identified core areas in the Heart of the West region that best represent the selected set of conservation elements (i.e. Natural Heritage Program species occurrences) at chosen target (goal) levels by using a simulated annealing algorithm applied to the conservation elements. To identify priority core areas for immediate conservation campaigns, we ranked each core area in terms of its irreplaceability and vulnerability (Pressey and Cowling 2001, Noss et al. 2002). The concept of irreplaceability provides a measure of the relative contribution different core areas make to reaching overall conservation goals, while a measure of vulnerability reveals the degree of current and future threats to individual core areas and helps determine which cores are in urgent need of immediate protection. We recommend that regional conservationists and land-use planners give the highest priority to those Heart of the West core areas that score high for both irreplaceable biological value and high degree of vulnerability to human threats.

METHODS

Study Area

Our study area includes the Wyoming Basins Ecoregion, as well as connecting lowland and upland habitat in the adjacent Southern Rockies and Utah High Plateaus Ecoregions (Figure 1, page 37). We aimed to ensure some landscape-scale connections to these ecoregions ensure long-term connectivity of wide-ranging focal species between the northern Rockies and southern Rockies. The landscapes and vegetation of the Heart of the West study area are considerably diverse, as the region spans numerous life zones (Knight 1994). The bulk of our study area, the Wyoming Basins Ecoregion, is dominated by sagebrush (*Artemesia tridentata*) steppe and various species of bunchgrass. Moving into the uplands of the Heart of the West that surround the basins, Rocky Mountain juniper (*Juniperus scopulorum*) delineates the lower boundary between shrub zones and coniferous zones. Douglas fir (*Pseudotsuga menziesii*) transitions to lodgepole pine (*Pinus contorta*) at higher

elevations. Two thirds of the rare plants endemic to Wyoming are found within the Heart of the West (Wyoming Natural Diversity Database 2005) in part due to this impressive diversity of life zones in the region.

The SITES Model

The enormity of the task of delineating core areas and linkages (Harris 1984) given our numerous targeted conservation elements made a manual approach to this conservation assessment very difficult. We used SITES (version 1.0, Andelman et al. 1999) to delineate core areas and landscape linkages within our study area by assembling and comparing alternative portfolios of planning units. SITES allows the user to identify an initial set of landscape patches that best represent a selected set of conservation elements at chosen target levels. The SITES model attempts to minimize reserve design “cost” while maximizing attainment of conservation goals in a compact set of core areas.

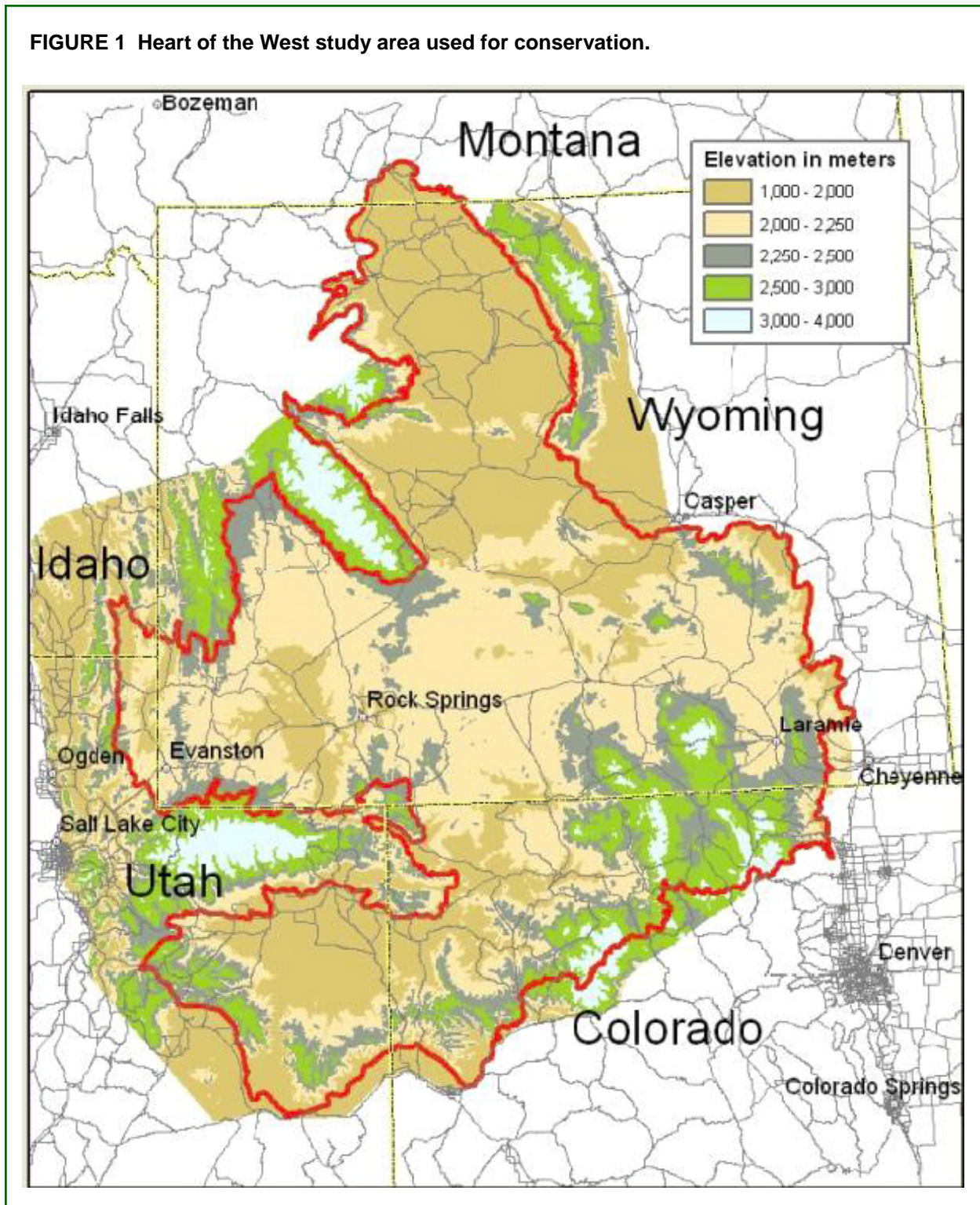
This set of objectives constitutes the “objective cost function,” in which:

$$\text{Cost} = \text{Area} + \text{Penalty} + \text{Boundary Length}$$

where Cost is the objective (i.e. for core areas to be minimized), Area is the number of hectares in all cores, Penalty is a cost imposed for failing to meet conservation target goals, and Boundary Length is a cost determined by the total boundary length of all core areas (thus causing core areas to be more compact and maximizing core to exterior ratios).

We used 15,642 hexagonal planning units of 1,250 hectares (ha) each. A hexagonal unit is preferable to other shapes or entities (e.g. square cells or watershed boundaries). It provides a relatively smooth output (as compared with square cells), approximates a circle - which has a low edge-to-area ratio, and the unit size remains constant. This reduces the likelihood of the algorithm rejecting larger units such as larger watersheds which might be interpreted as having a greater cost than smaller units (Wilmer, in prep). We chose the 1,250 ha.

FIGURE 1 Heart of the West study area used for conservation.



size based on a sensitivity analysis that compared SITES results with different sized planning units (as described in Jones et al. 2004).

We set the SITES penalty value for all conservation elements at 1.0 (the potential range is from 0 to 1.0) so that each planning unit was equivalent in terms of cost and the algorithm was unconstrained in selecting where to achieve its goals. This ensured that only areas with less targets would be viewed as having “higher costs.” This increased the chances that all conservation elements had an equal chance of being represented in the final solution at approximately the levels for which we targeted them. Each time the SITES model is run, it performs 1,000,000 iterative attempts to identify the minimum cost solution per run. We ran the model with different variations of the SITES input parameters, such as varying the boundary-length modifier to achieve different degrees of planning unit “clumping.” We also adjusted some of our conservation target goals (such as amount of Natural Heritage species locations we wanted in solution) in these test runs and assessed the effectiveness of the final solution in terms of capturing all of our representation, special element, and focal species target goals within the Heart of the West (Noss et al. 2002, Miller et al. 2003). The final SITES solution adopted as the proposed conservation network was the one that we believed to best meet all of our conservation goals for the region.

Representation Analysis

The actual level of representation necessary to ensure, when adequately protected, persistence of any given land cover type depends on many different variables, including the overall area occupied by each land cover type, and the degree of connectivity of the land cover type. Noss and Cooperrider (1994) observed that, “science cannot tell us precisely how many times or in what size reserves each...ecosystem type must be represented to be viable.” We propose, therefore, that representation percentages be used to identify elements that may be relatively under-represented within the proposed network, and not to

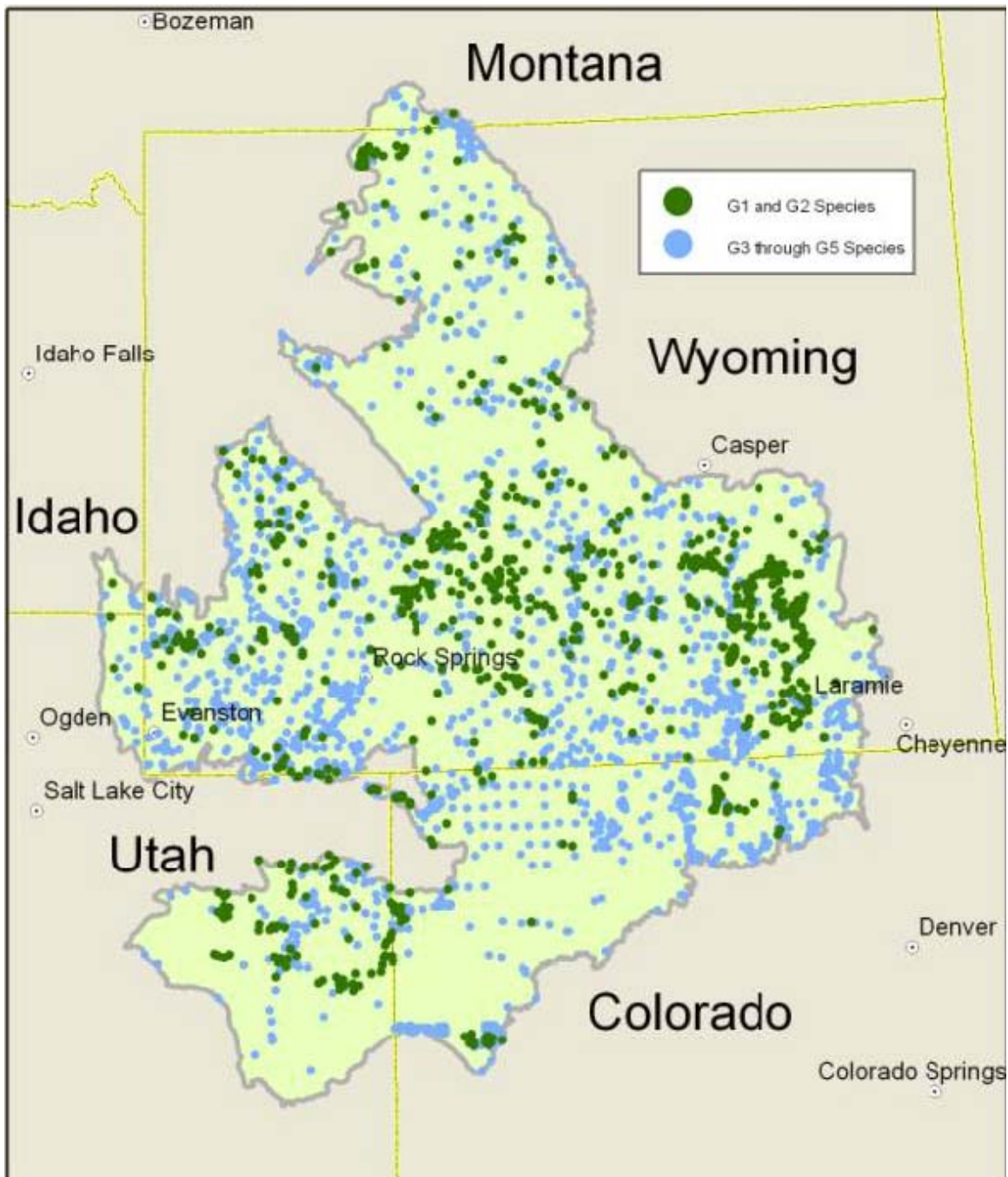
speculate what level of representation would provide for viability and persistence of all communities within the network. We utilized a 25% representation goal for all landcover types as often recommended by The Nature Conservancy (Groves et al. 2000) and used by Noss et al. (2002) for the Utah-Wyoming Mountains Ecoregional Plan.

Special Elements

We assembled Natural Heritage Program (NHP) element occurrence data for the study area from the state Heritage Programs in Wyoming, Montana, Colorado, Utah and Idaho (Figure 2, page 39). We included 161 plant and 42 animal species in our final list of target species. The animal targets included 13 mammals, 7 reptiles, 3 amphibians, 13 birds, and 6 species of fish. This list was derived from The Nature Conservancy’s target list for the Wyoming Basins Ecoregion, plus all S1 (critically imperiled at the state level) and S2 (imperiled at the state level) species within the Book Cliffs in Utah and the portion of the Southern Rockies in Colorado and Wyoming that fall within our study area. Using SITES, we targeted 100% of G1 (critically imperiled globally) and G2 (imperiled globally) occurrences, and 25%-75% of all species occurrences of lower rank to be included in cores and linkages. We selected these target levels based on those used by Noss et al. (2002) in the Utah-Wyoming mountains (i.e. 100% of G1 and G2 species), as well as the number of total occurrences in the study area, and target goals set for the same species by Freilich et al. (2001) in the Wyoming Basins. Using The Nature Conservancy guidelines (Comer 2001, The Nature Conservancy 2001b), we corrected for unequal survey efforts (and thus over-representation in the SITES solution) for NHP species by capping targets at 25 occurrences. This was important to do in light of some very high profile species such as federally listed species that are surveyed for far more often than most other species in the region.

Stream reaches containing conservation populations of cutthroat trout were another special element used in the

FIGURE 2 Natural Heritage Program (NHP) element occurrence data for the study area from state Heritage Programs.

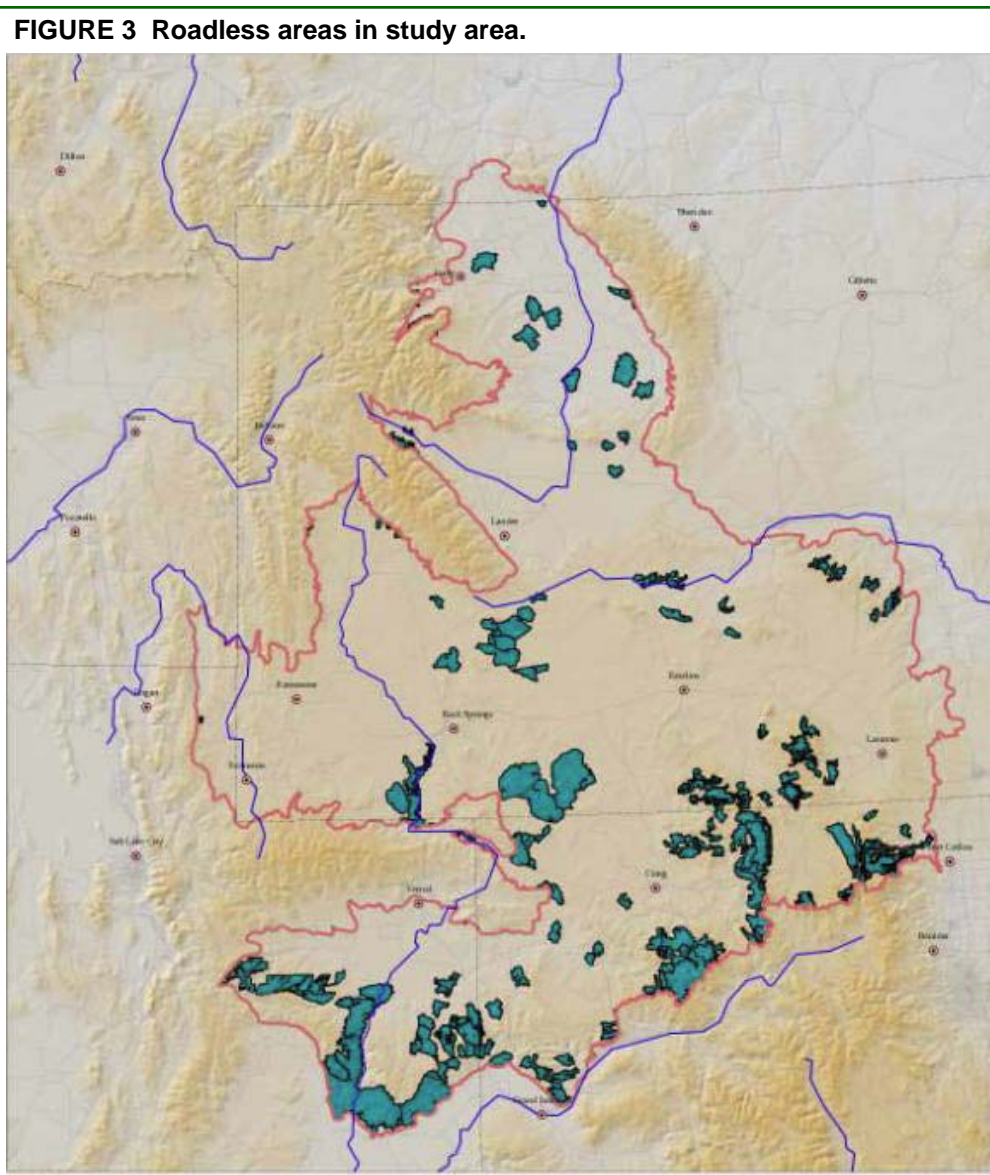


SITES analysis. We chose this element because they are indicator species (Behnke 2002) and because of the importance of cutthroat trout to stream ecosystems, the severe decline of native trout species in the region, and also because this element was not likely to have been covered by the (terrestrial) focal species analyses and land cover representation analysis. We targeted 100% of all occurrences of cutthroat trout stream segments for inclusion in a conservation network.

Due to the important conservation value of roadless areas (Hitt and Frissell 1999, Wilcove et al. 2000, Strittholt and

DellaSala 2001), we chose to include 100% of remaining roadless areas in the final network. These roadless areas are comprised of all citizen-inventoried and agency-inventoried roadless areas and all lands with GAP 1 status (Figure 3).

The results of the sage grouse and wolf habitat suitability models were used as inputs into the SITES analysis. We targeted 100% of all top-scoring sage grouse habitat, and 25% of areas that scored in the second highest sage grouse habitat category to be included in cores and linkages. We targeted 75% of all top-scoring wolf habitat,



and 25% of areas that scored in the second highest wolf habitat category to be included in cores and linkages. We set these particular targets based on trial SITES runs, expert opinion and focal species target goals used in other conservation network designs (i.e. Miller et al. 2003).

Finalizing Linkages

SITES also reported how often each planning unit was included in the initial set of cores during the trial runs. This information helped us then delineate linkages after the cores were chosen. Even if these potential “connecting units” sometimes were not included in the final solution model, if they were selected once that meant they likely included one or more of our targets. This justified using these planning units as building blocks to construct linkages between cores, along with natural ungulate migration routes, stream linkages, and lightly roaded, public land. When stream or river linkages were used as the basis for linkages, they were used as the backbone of the linkage, with at least a 0.5 km buffer on either side of the stream or river.

Expert Assessment

Quantitative data on which to evaluate conservation priorities are always limited. Thus, we recognized that the SITES analysis would need to be supplemented by expert opinion. Practitioners, local scientists and conservationists can provide valuable and often undocumented information on conservation elements, important habitats, threats and feasibility of site protection. In addition to providing key information, involvement of experts can simultaneously help develop strong partnerships, provide necessary peer review, and generally help garner acceptance and credibility of the final conservation network (Noss 2003). Types of expert assessment utilized in this process included expert peer review by regional scientists of focal species accounts, focal species habitat models, and the final Heart of the West Conservation Plan (Jones et al. 2004), as well as

expert workshops. Workshops were conducted with scientists, local conservationists, and Natural Heritage Program and TNC staff to gather input on threats, additional information on conservation elements and important habitats, and placement of cores and linkages. The input and advice generated through these peer review processes were used to fine-tune the final boundaries of core areas and linkages, as well as improve the Conservation Plan.

Irreplaceability and Vulnerability Analysis

A key concept in conservation planning is irreplaceability (Pressey and Cowling 2001). Irreplaceability provides a measure of the relative contribution different core areas make to reaching overall conservation goals, thus helping planners prioritize protection for various core areas in a conservation network. Irreplaceability can be described in two ways: (1) the likelihood that a particular area is needed to achieve an explicit conservation goal, or (2) the extent to which the options for achieving an explicit conservation goal are narrowed if an area is not conserved. A core area that ranks high in terms of irreplaceability is essential to meeting a particular goal; an example would be a core area that contains the only known occurrence of a species in the region. Conversely, a core with a very low irreplaceability value might have a number of replacements.

We assigned irreplaceability values to core areas based on their contribution to the goal of (1) protecting Natural Heritage Program species in the study area, (2) protecting 100% of stream segments with Conservation Populations of cutthroat trout, (3) protecting 100% of all roadless areas, (4) representing at least 25% of each land cover type, (5) protecting 75% of top scoring wolf habitat, and 25% of second highest scoring wolf habitat, and (6) protecting 100% of best-scoring class of sage grouse habitat, and 25% of second best-scoring class of sage grouse habitat in the study area.

To allow for direct comparison of the ability of core areas to meet goals for multiple targets, we first normalized the quantity of any particular by dividing the amount by the

standard deviation, and then calculated a standard Z-score for each core area based on how well that core area did in capturing conservation elements (Jeo 2002). The Z-score was calculated for the six categories of targets (described above) within a core area. This procedure allowed us to directly compare the number of targets in each core using meaningful units, since the mean Z-score for the entire study area is, by definition, approximately 0, and 1 unit represents one standard deviation from the mean value. Using Z-scores allows values to be combined such that each target receives equal weight and with explicit consideration of the relative rarity of any target. For example, in order to rank core areas based on NHP data, we combined all NHP targets into a single index score. This method was particularly helpful in determining irreplaceability of small core areas compared to large core areas.

Another key consideration in conservation planning is threat or vulnerability (Margules and Pressey 2000). Understanding the current and future threats to individual core areas helps determine which cores are in urgent need of immediate protection, and can help conservationists prioritize core areas for attention while also developing specific strategies and conservation plans for cores. Based on the significant threats to core areas (and the wildlife they support) posed by oil and gas development (Comer 1982, Van Dyke and Klein 1996, Lyon 2000, Ingelfinger 2001, Weller et al. 2002), and considering the use of road density as a secondary metric of human threats to core areas (Brattstrom and Bondello 1983, Mech et al. 1988, Hobbs and Huenneke 1992, McIntyre and Lovoral 1994, Mace et al. 1996, Gelbard and Belnap 2003) we calculated Z-scores for the vulnerability of each core based on road density in that core, current oil and gas well density in the core, and degree of future oil and gas activity threatening the core area.

Based on Z-score analysis, we assigned a vulnerability score of 0-100 to each core area. Core areas were then plotted on a graph of irreplaceability (y axis) versus vulnerability (x-axis) and the graph divided into four quadrants (Margules and Pressey 2000, and Noss et al. 2002). The upper right quadrant, which includes core

areas with high irreplaceability and high vulnerability, comprises the highest priority core areas for conservation.

RESULTS

The final conservation network based on what we determined to be the final SITES run identified the most efficient and compact portfolio of core areas and linkages (Figure 4, page 43) containing the 247 targets (including all focal species targets, special elements, representation analysis) at, above, or very close to the pre-assigned target levels (Table 1, page 44). To increase connectivity between core areas, we added a few planning units by hand to the final solution in areas representing key linkages. Whenever possible these manually added planning units followed perennial watercourses and known important migration linkages for pronghorn (*Antilocapra Americana*), deer (*Odocoileus hemionus*), and elk (*Cervus elaphus*).

The final conservation network solution included a total of 8,387,190 ha (or 44.9 % of the study area) in the network portfolio. The final network included all existing protected areas (i.e. GAP1 lands) because all of these units are roadless and the model incorporated 100% of roadless areas into the conservation network. As the SITES model did not distinguish private lands from public lands when assembling the conservation portfolio, private lands are amply represented (29% of the network, Figure 5, page 45). For planning purposes, we identified and named 28 of the larger core areas in the network (Figure 4). These key core areas range from 32,500 to 1,367,000 hectares in size. Overall, this assemblage of proposed conservation sites met our goals represented by our three conservation tracks (representation, special elements, and focal species), with some conservation elements being represented well above their specified target levels.

The SITES model generally achieved our target goals for (land cover) representation, special element incorporation, and focal species habitat representation. Land cover targets were met at levels between 107% and 349% of the original target goals for those land cover

FIGURE 4 Private land holdings (blue) within Heart of the West conservation network core areas and linkages.

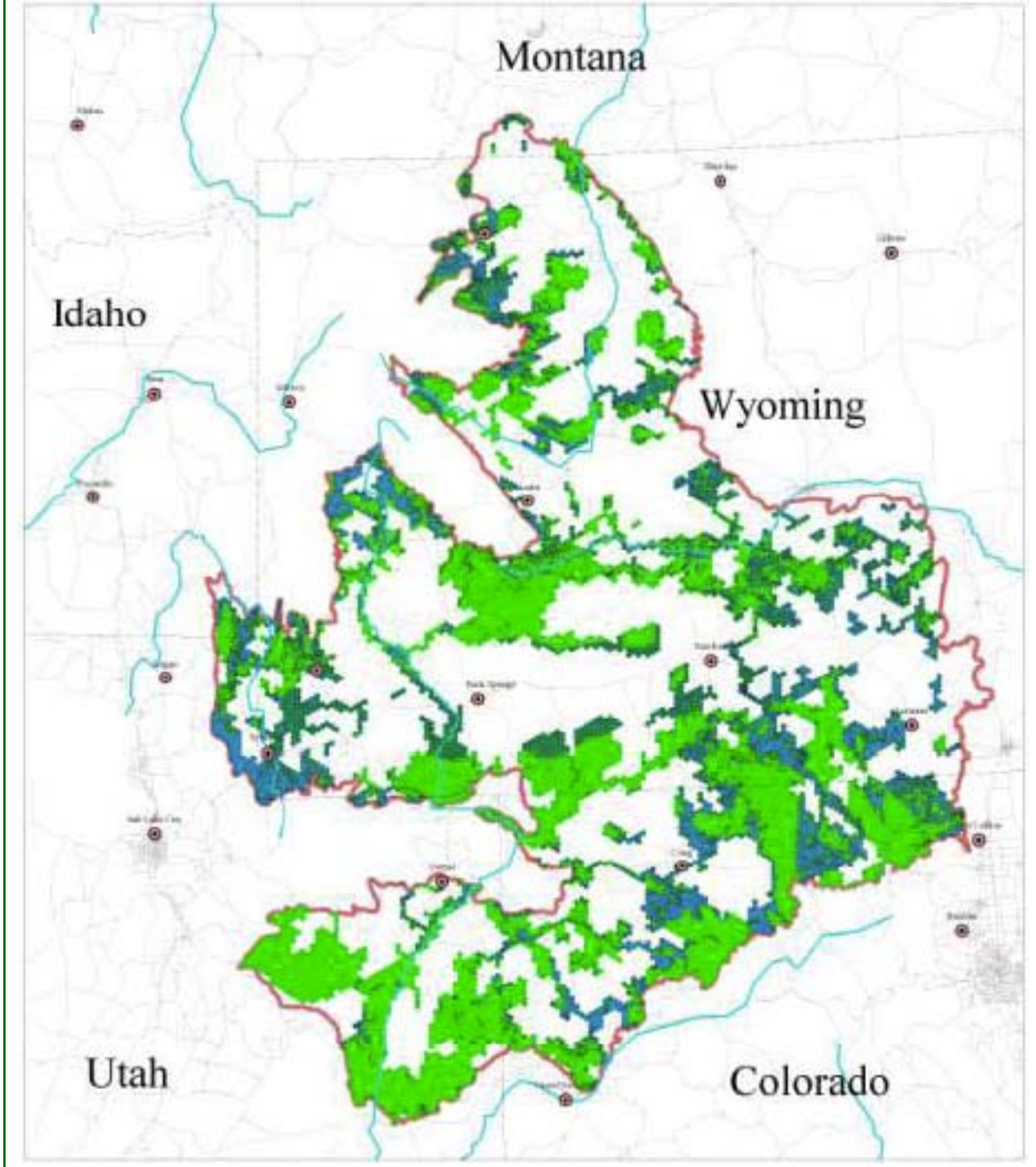


TABLE 1 Target Goals, and Percentages Achieved in the Heart of the West Conservation Network

Conservation Element	Total in Study Area (hectares)	Amount Targeted	Amount Achieved in Network (hectares)	Percent of Total (in study area) in Final Network	Percent of Target Achieved in Final Network
Good Wolf habitat	6,281,519	1,570,377 (25%)	2,348,820	37.4%	149.60%
Best wolf habitat	188,615	141,461 (75%)	145,948	77.4%	103%
Good sage grouse habitat	7,604,780	1,901,195 (25%)	3,306,773	43.5%	174%
Best sage grouse habitat	476,308	476,308 (100%)	442,426	93%	93%
Cutthroat trout population segments	17,157 (linear hectares)	17,157 (100%)	17,157	100%	100%
Roadless areas	199,864	199,864 (100%)	199,864	100%	100%
Land cover types	varies ^a	25% of each type	Described in Jones et al. 2004	varies for each type	107% -349% of the target
NHP species, G1s and G2s	varies ^a	100% of each species	Described in Jones et al. 2004	varies for each species	75% -1896% of the target ^b
NHP species, G3s through G5s	varies ^a	25% to 75% of each species ^c	Described in Jones et al. 2004	varies for each species	70% - 608% of the target ^b

^a Land cover totals and total number of NHP species in study area are described in Jones et al. 2004.

^b Some of the targets were significantly over-represented due to a clear sampling bias in our study area for federally listed and candidate species such as bald eagle, mountain plover, and boreal toad. Again, it is possible to achieve well over 100% of a target of 100% when occurrences are capped at 25.

^c G3 to G5 species target goals ranged from 25% to 75% of occurrences, based on the number of occurrences in study area, and target goals set for these species in The Nature Conservancy's Ecoregional Plan for the Wyoming Basins. Individual target goals, and final results achieved, for these species are described in Jones et al. 2004.

types (individual target goals, and final results achieved, for each land cover type are described in Jones et al. 2004). Overshooting the target goal was usually the result of redundancy in certain habitat types such as sagebrush that were represented in large quantities to achieve focal species habitat goals. Focal species habitat targets were also successfully incorporated in the final conservation network. Other than the “best sage grouse habitat” category (represented at 93% of the target goal), all focal species classifications were represented in the network at levels of 100% of target or greater (Table 1). Special element targets were variably met in the final portfolio. Of the 203 NHP species incorporated in special element mapping, 21 did not achieve the 100% representation goal in the final conservation network. G1 and G2 species targets were met at least the 75% level, and G3 to G5 targets were met at least the 50% level. Some of the targets were significantly over-represented. This was due to a clear sampling bias in our study area for federally listed and candidate species such as bald eagle (*Haliaeetus leucocephalus*), mountain plover (*Charadrius montanus*), and boreal toad (*Bufo boreas*). These species are surveyed far more frequently than others and thus appear to be very abundant in the study area, and easily picked up in abundance in all SITES runs.

The final conservation network also helped meet other, tangential, planning goals that were not direct inputs into the SITES model. For example, our proposed set of cores and linkages included over 67 % of all perennial streams, and 63% of The Nature Conservancy’s portfolio sites, in the study area. The network also captured existing suitable habitat for other focal species (such as bighorn sheep, beaver, bison and grizzly bear) at the level of 50% or greater.

Irreplaceability and Vulnerability Analysis

Drawing upon the approach of Margules and Pressey (2000) and Noss et al. (2002), we plotted key (named, Figure 4) core areas on a graph of irreplaceability (y-axis) versus vulnerability (x-axis) and divided the graph into

four quadrants (Figure 6). The upper right quadrant, which encompasses clusters with high irreplaceability and high vulnerability, is generally the highest priority for conservation. This top tier of core areas is followed by the upper left and lower right quadrants (moderate priority), and finally, by the lower left quadrant, encompassing cores that are relatively replaceable and face less severe threats (Noss et al. 2002). One can also prioritize cores within a quadrant; for example, core areas in the lower left quadrant that are higher on the irreplaceability axis (y-axis) would warrant higher priority than cores lower in irreplaceability.

We urge regional conservationists and activists to give high priority to those core areas in the upper left quadrant over the lower right quadrant (Figure 6, page 47). Areas of high and irreplaceable biological value deserve conservation action even if not highly threatened today, and protection of these areas while they are relatively ecologically intact is more efficient than having to restore them in the future (Noss et al. 2002).

The degree of current oil and gas production in core areas was a major factor in the irreplaceability and vulnerability analysis. Often, the SITES results included areas with significant levels of energy production, usually because they were embedded deep within a core or were essential for connectivity, or still housed important NHP targets. For the final conservation network, we refer to these core area planning units with high numbers of oil and gas wells as Core Recovery Areas and Linkage Recovery Areas. Long-term Core Recovery Areas are those hexes with more than 25 wells per planning unit — or more than one well per 50 acres — and Short-term Core Recovery Areas are those with between 5 and 25 oil and gas wells per planning unit. It is likely that the biggest threat to Heart of the West core areas in the near future is additional oil and gas extraction efforts (High County News 2003a, 2003b). This factor weighed heavily in the vulnerability analysis. Figure 7, page 48, depicts the degree of the future oil and gas threat facing core areas.

FIGURE 6 Irreplaceability versus vulnerability graph. The X axis measures Z-scores for vulnerability. Moving along the X-axis from left to right, cores are more vulnerable to degradation or loss of protection. The Y axis measures Z-scores for irreplaceability; cores higher on this axis are more irreplaceable. Cores in the upper right hand quadrant have the highest priority for protection, as they are both irreplaceable, and vulnerable.

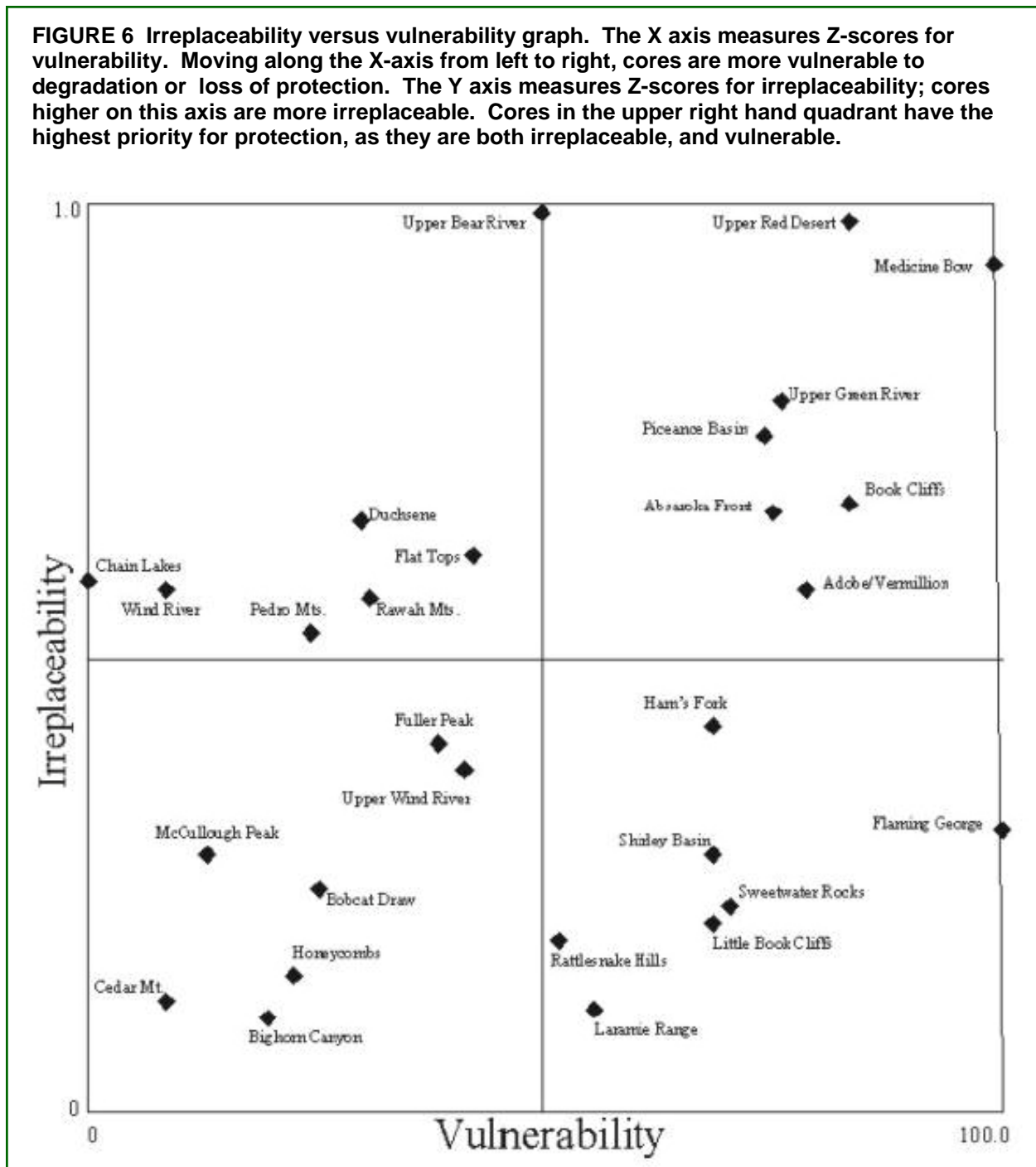
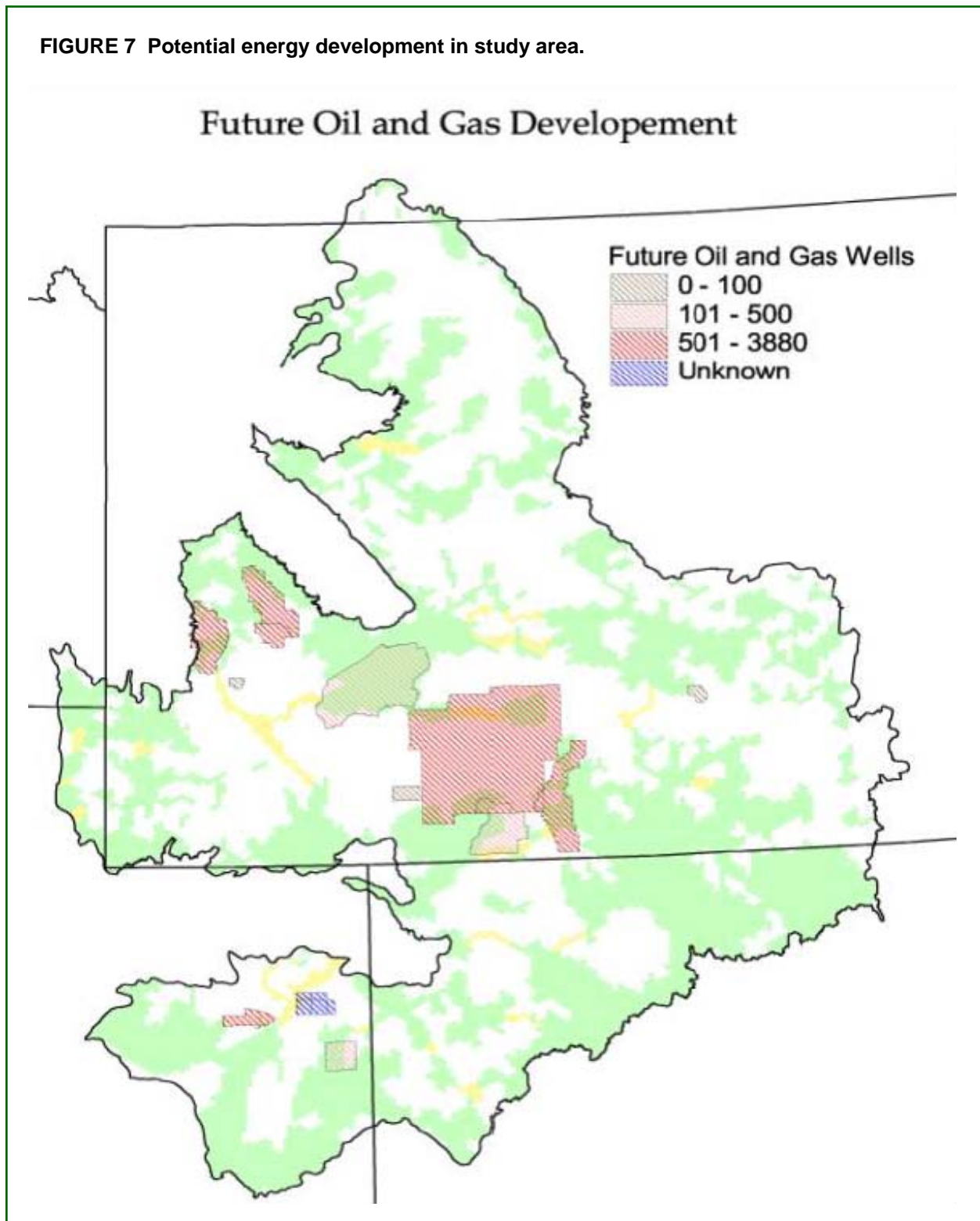


FIGURE 7 Potential energy development in study area.



CONCLUSION

The methods used in this exercise combine various approaches (representation analysis, special element mapping, and focal species habitat modeling) that are often applied separately in large scale conservation planning. This three-track approach to designating core areas and linkages within a proposed network of reserves, combined with irreplaceability and vulnerability analysis of core areas, gives practitioners the benefit of a balanced, yet systematic and rigorous approach to conservation site selection, along with a useful tool to set conservation priorities within the network. However, to be most helpful, additional vulnerability analyses should be conducted in the future as the level of human threats to core areas change. Conservation priorities on the ground are always changing over time as areas are protected or are lost to development. Therefore the best exercises in conservation planning are iterative, to account for changes in development pressures as well as collection of new and/or better data in areas important for biodiversity.

Following the precautionary principle, the core areas highest in both irreplaceability and vulnerability (featured in upper-right quadrant of Figure 6) should have the highest priority for protection. However, all core areas should be protected if the opportunity arises. A caveat with basing conservation priorities on computer mapping exercises is that the data that informs irreplaceability analyses and determines whether a core area is ranked in the highest priority (1 and 2) quadrants, is itself sometimes based on incomplete information or analysis. For example, biases in NHP databases are difficult to avoid. Usually, a lack of element occurrences in a given area reflects lack of surveys in this region, rather than a lack of rare and endemic species. In the future, as additional surveys are conducted in certain core areas, sites that are currently lower priorities for conservation may move upwards on the irreplaceability axis (Noss et al. 2002).

There are similar cautions regarding representation and focal species analysis. For instance, the assumption that

representation of similar percentages of all land cover types adequately protects the myriad of species that use those vegetation types (the coarse filter hypothesis), cannot be seriously tested short of a full inventory of an area's biota. In terms of focal species modeling, our individual core areas do not necessarily include the specific waters or lands needed to maintain viable populations of each target in each core. Rather, the overall network was designed under the working assumption that, assuming cores are relatively connected across the landscape, viable populations of all focal species could be maintained across the Heart of the West. Practitioners and scientists utilizing our conservation network may want to validate this assumption.

Only 4.1 % of the proposed Heart of the West Wildlands Network is already in some form of protective federal status (i.e. GAP 1 or 2 status lands, which are primarily managed for maintenance of biological diversity or natural values). A concerted effort by conservationists, local communities, land managers and politicians will be required to increase the amount of area in cores and linkages that are protected at the state and federal level. However, while we consistently use terms such as "reserves" and "protect," we stress that goal achievement in this conservation planning exercise can readily be met through means other than what is traditionally thought to be the implementation tools for reserve design: conservation easements; direct fee acquisition; and congressional, administrative executive, or agency designations of special management areas (ranging from Research Natural Areas to national monuments to wilderness). In fact, the practitioners and conservationists currently implementing the Heart of the West program are increasingly turning to new public land implementation strategies that focus chiefly on changes in agency management. The chief way to bring about the necessary management is by both proactively and legally affecting positive change in grazing prescriptions (through the permit renewal process), designated ORV routes (through travel plan revisions), and energy development and other use-zoning (through land management plan revisions).

Currently, 29% of our proposed cores and linkages for the Heart of the West are comprised of privately held lands. Private lands offer different and innovative options for land protection, such as “conservation ranches,” private nature reserves, stewardship assistance and other management agreements with landowners, and sale to, or easements with, organizations who carry out all of the above activities, such as The Nature Conservancy and other land trusts. Those working to implement the Heart of the West conservation network intend to engage private landowners who own land in cores and linkages, and work towards controlled road access, management for biodiversity conservation purposes, and toleration of carnivores.

The three track approach to conservation network design combined with irreplaceability/ vulnerability planning gives practitioners a sound basis to make conservation decisions in an uncertain and quickly changing world. This is clearly evident in the Wyoming Basins Ecoregion of the Heart of the West which is “Ground zero” for the current push to develop new sources of oil and gas. The Heart of the West is currently facing habitat fragmentation and ecosystem degradation never before witnessed in this region. For this reason, it is imperative that the proposed conservation network for the Heart of the West is integrated into land use policies, plans and actions for this region of the middle Rockies. We urge Native Americans, conservation groups, local communities, mineral extraction companies, and government land management agencies to unite in working toward its implementation.

ACKNOWLEDGEMENTS

This manuscript was partly derived from the full conservation plan for the Heart of the West (Jones et al. 2004), authored by AJ, EM, KD and JC as well as T. Lind, J. Freilich, K. Robinson, L. Flaherty, and J. Kessler. The full conservation plan, and associated focal species natural history literature reviews and habitat models was reviewed by 67 individuals representing government agencies and academic institutions. The research,

design and mapping efforts behind the Heart of the West conservation plan were funded in part by the following foundations: George and Delores Dore Eccles, JEPS, Maki, Peradam, Switzer, Turner, Walbridge, and Wilburforce.

We engaged very similar methods as those used by Noss et al. (2002) in their conservation assessment for the adjacent Utah-Wyoming Mountains Ecoregion, to ensure that our conservation network design and their assessment had strong agreement along the common boundary. Our work complements The Nature Conservancy’s (TNC) Ecoregional Plan for the Wyoming Basins Ecoregion (Freilich et al. 2001), which did not utilize focal species analyses, connectivity modeling, threats analysis or an annealing algorithm, but instead utilized manual delineation of portfolio sites based on special elements and representation analysis.

LITERATURE CITED

- Andelman, S., I. Ball, F. Davis, and D. Stoms. 1999. SITES V 1.0: An analytical toolbox for designing ecoregional conservation portfolios. A manual prepared for the Nature Conservancy.
- Bailey, R.G. 1995. Descriptions of the eco-regions of the United States. USDA Forest Service, Misc. Publication #1391. US Government printing Office: 1995-393-835.
- Behnke, R.J. 2002. Trout and salmon of North America. New York: Chanticleer Press, Inc.
- Bennett, G. and P. Wit. 2001. The development and application of Ecological Networks: A review of proposals, plans and programmes. AIDEnvironment and IUCN, Amsterdam. 137 pp.
- Bonn, A., A.L Rodrigues, and K.J. Gaston. 2002. Threatened and endemic species: are they good indicators of patterns of biodiversity on a national scale? Ecology Letters 5:733-741.
- Brattstrom, B.H. and M.C. Bondello. 1983. Effects of off-road vehicle noise on desert vertebrates. Pp. 7206 in: (R.H. Webb and H.G. Wilshire, eds.) Environmental effects of off-road vehicles: impacts and management in arid regions. Springer-Verlag, New York.
- Carroll, C. R.F. Noss, and P.C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications 11:961-980.

- Carroll, C., R.F. Noss, P.C. Paquet, and N. H. Schumaker. 2003. Use of population viability analyses and reserve selection algorithms in regional conservation plans. *Ecological Applications* 13(6):1773-1789.
- Comer, P. 2001. Observations and recommendations for setting conservation goals in ecoregional plans. The Nature Conservancy, Boulder, CO.
- Comer, R.D. 1982. Understanding secondary effects of development on wildlife resources in mitigation planning. Pps. 16-31 in: (Comer et al., eds.) *Proceedings of the second symposium on issues and technology in the management of impacted western wildlife*. Thorne Ecological Institute, Boulder, CO.
- Foreman, D., K. Daly, R.F. Noss, M. Clark, K. Menke, D.R. Parsons, and R. Howard. 2003. New Mexico highlands wildlands network vision. *Wildlands Project*, Richmond, VT.
- Freilich, J., B. Budd, T. Kohley, and B. Hayden. 2001. The Wyoming Basins Ecoregional Plan. The Nature Conservancy, Lander, WY.
- Gelbard, J.L. and J. Belnap. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. *Conservation Biology* 17:420-432.
- Groves, C. 2003. *Drafting a Conservation Blueprint: A practitioner's guide to planning for biodiversity*. Island Press, Washington, D.C.
- Groves, C., L. Valutis, D. Vosick, B. Neely, K. Wheaton, J. Touval, and B. Runnels. 2000. *Designing a geography of hope: a practitioner's handbook for ecoregional conservation planning*. The Nature Conservancy, Arlington, Virginia.
- Harris, L.D. 1984. *The fragmented forest: island biogeography theory and the preservation of biotic diversity*. University of Chicago Press, Chicago.
- High Country News. 2003a. The Red Desert braces for a gas boom. http://www.hcn.org/servlets/hcn.Article?article_id=14170.
- High Country News. 2003b. In the rush to get out the gas, wildlife gets short shrift. http://www.hcn.org/servlets/hcn.Article?article_id=14171.
- Hobbs, R.J. and L.F. Huenneke. 1992. Disturbance, diversity and invasion: implications for conservation. *Conservation Biology* 6: 324337.
- Jeo, R.M. 2002. Extending conservation network framework to the North Coast region of British Columbia, Canada. *Round River Conservation Studies*, Salt Lake City, UT.
- Jones, A., J. Catlin, T. Lind, J. Freilich, K. Robinson, L. Flaherty, E. Molvar, J. Kessler, and K. Daly. 2004. *Heart of the West Conservation Plan*. Wild Utah Project, Salt Lake City, UT.
- Hitt, N.P. and C.A. Frissell. 2000. An evaluation of wilderness and aquatic biointegrity in western Montana. Pg. 138-142 in :McCool, S.F., D.N. Cole, W.T. Borrie, J. O'Loughlin, comps. 2000. *Wilderness science in a time of change conference-Volume 2: Wilderness within the context of larger systems*; 1999 May 23-27; Missoula, MT. *Proceedings RMRS-P-15-VOL-2*. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Hobbs, R.J. and L.F. Huenneke. 1992. Disturbance, diversity and invasion: implications for conservation. *Conservation Biology* 6: 324337.
- Ingelfinger, F.M. 2001. The effects of natural gas development on sagebrush steppe passerines in Sublette County, Wyoming. M.S. Thesis, Univ. of Wyoming, 110 pp.
- Knight, R.L. 1994. *Mountains and plains: the ecology of Wyoming landscapes*. Yale University Press, New Haven, CT. 338 pp.
- Lindenmayer, D.B., A.D. Manning, P.L. Smith, H.P. Possingham, I. Oliver, and M.A. McCarthy. 2002. The focal species approach and landscape restoration: a critique. *Conservation Biology*. 16:338-345.
- Lyon, A.G. 2000. The potential effects of natural gas development on sage grouse (*Centrocercus urophasianus*) near Pinedale, Wyoming. M.S. Thesis, Univ. of Wyoming, 121 pp.
- Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. *Journal of Applied Ecology* 33: 13951404.
- Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. *Nature* 405: 243-253.
- McIntyre, S. and S. Lovoral. 1994. Predicting richness of native, rare and exotic plants in response to habitat and disturbance variables across a variegated landscape. *Conservation Biology* 8: 521531.
- Mech, L.D., S.H. Fritts, G.L. Radde and W.J. Paul. 1988. Wolf distribution and road density in Minnesota. *Wildlife Society Bulletin* 16: 8587.
- Miller, B., R. Reading, J. Strittholt, C. Carroll, R. Noss, M. Soule, O. Sanchez, J. Terborgh, D. Brightsmith, T. Cheeseman, and D. Foreman. 1998. Using focal species in the design of nature reserve networks. *Wild Earth* 8: 81-92.
- Miller B., D. Foreman, M. Fink, D. Shinneman, J. Smith, M. DeMarco, M. Soulé, B. Howard and T. Hogan. 2003. *Southern Rockies Wildlands Network Vision*. The Southern Rockies Ecosystem Project, The Denver Zoological Foundation and The Wildlands Project, Boulder, CO.
- Noss, R.F. 2003. A checklist for wildlands network designs. *Conservation Biology* 17:1270-1275.

- Noss, R.F., J.R. Strittholt, K. Vance-Borland, C. Carroll, and P. Frost. 1999. A conservation plan for the Klamath-Siskiyou ecoregion. *Natural Areas Journal* 19:392-411.
- Noss, R. F. and A.Y. Cooperrider. 1994. *Saving Nature's Legacy: Protecting and Restoring Biodiversity*. Island Press, Washington, DC.
- Noss, R. F., C. Carroll, K. Vance-Borland and G. Wuerthner. 2002. A Multicriteria Assessment of the Irreplaceability and Vulnerability of Sites in the Greater Yellowstone Ecosystem. *Conservation Biology* 16(4): 895-908.
- Pressey, R.L. and R.M Cowling. 2001. Reserve selection algorithms and the real world. *Conservation Biology* 15: 275-277.
- Redford, K.H., P. Coppolillo, E.W. Sanderson, G.A.B. da Fonseca, E. Dinerstein, C. Groves, G. Mace, S. Maginnis, R.A. Mittermeier, R. Noss, D. Olson, J.G. Robinson, A.
- Vedder, and M. Wright. 2003. Mapping the conservation landscape. *Conservation Biology* 17:116-131.
- Rumsey, C., M. Wood, B. Butterfield, P. Comer, D. Hillary, M. Bryer, C. Carroll, G. Kittel,
- K.J. Torgerson, C. Jean, R. Mullen, P. Iachetti, and J. Lewis. 2003. Canadian Rocky Mountains Ecoregional Assessment, Volume One: Report. Nature Conservancy of Canada, Victoria, B.C.
- Scott, J.M, F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves and J. Estes. Nature reserves: do they capture the full range of America's biological diversity? 2001. *Ecological Applications* 11: 999-1007.
- Soulé, M.E. and J. Terborgh, editors. 1999. *Continental Conservation: Scientific foundations of regional reserve networks*. Island Press, Washington, D.C. 227 pp.
- The Nature Conservancy, Conservation Science Division. 2001a. TNC Ecoregions. Arlington, Virginia The Nature Conservancy. 2001b. Southern Rocky Mountains: an ecoregional assessment and conservation blueprint. The Nature Conservancy, Boulder, CO.
- Van Dyke, F., and W.C. Klein, 1996. Response of elk to installation of oil wells. *J. Mamm.* 77(4):1028-1041.
- Weller, C., J. Thomson, P. Morton and G. Aplet. 2002. *Fragmenting our lands: the ecological footprint from oil and gas development*. The Wilderness Society. Denver, CO.
- Wilmer, B. In prep. Prioritizing conservation efforts Using SITES: a sensitivity analysis.
- Wilcove, D., D. Rothstein, J. Dubow, A. Phillips and E. Losos. 2000. Leading threats to biodiversity-what's imperiling U.S. species. Pages 237-254 in: (Stein, B.A., L.S. Kutner, and J.S. Adams, eds.) *Precious heritage-the status of biodiversity in the United States*. The Nature Conservancy and the Association for Biodiversity information. Oxford University Press, New York. 399 pp.
- Wyoming Natural Diversity Database 2005. <http://uwadmnweb.uwyo.edu/wyndd/>.