A Biological Conservation Assessment for the Utah-Wyoming Rocky Mountains Ecoregion:

Report to The Nature Conservancy

July 2001

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EXECUTIVE SUMMARY

This report presents a conservation assessment of the Utah-Wyoming Rocky Mountains Ecoregion (UWRM; Fig. E1), as a contribution to the ecoregional planning efforts of The Nature Conservancy and as part of the foundation for site-level planning. It is complementary to a report to the Greater Yellowstone Coalition on the Greater Yellowstone Ecosystem (GYE), which forms the northwestern portion of the UWRM.

The approach taken in this study is representative of regional-scale or ecoregional conservation planning, which has become the standard approach for conservation organizations and agencies worldwide. Ecoregional conservation planning differs from conventional land-use planning in that regions are defined ecologically rather than politically. For example, the GYE was first defined by John and Frank Craighead as an area large enough to sustain the disjunct Yellowstone population of grizzly bears. That definition has expanded to encompass other qualities of the ecosystem, including intact watersheds and mountain ranges.

A fundamental quality of ecoregional conservation planning is that it is systematic and, therefore, superior in many ways to opportunistic or politically-biased planning. Among the key attributes of systematic conservation planning are explicit goals and quantitative targets, objective methods for locating new reserves to complement existing ones, and explicit criteria for implementing conservation actions.

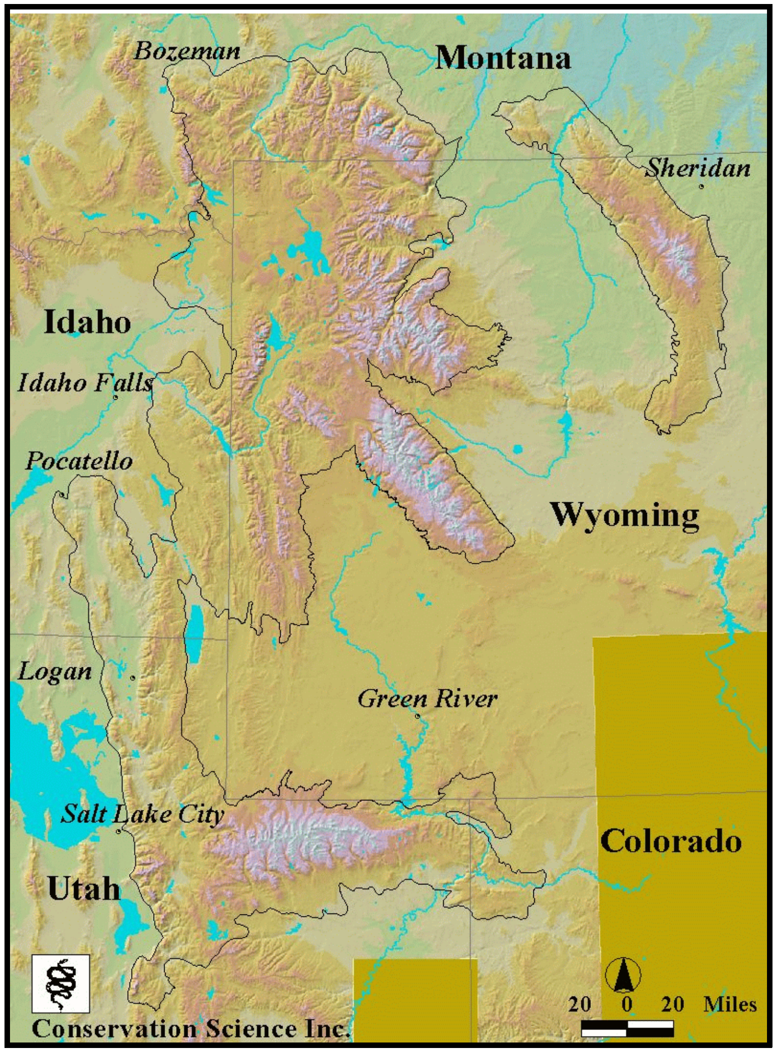

Figure E1. Utah-Wyoming Rocky Mountains (UWRM) Ecoregion.

Approach

We sought to identify high-priority sites within the UWRM that have the most to lose, in terms of biodiversity, if not protected. These sites are often irreplaceable, in that the values they contain cannot be replicated elsewhere. Across much of this ecoregion and the West in general, measures other than the traditional “fee simple” acquisition have become the primary tools of the conservation community. Partnerships with private landowners (e.g., ranchers), conservation easements, and agency designations are among the tools available. Nevertheless, on private lands of very high biodiversity value or at immediate risk of degradation by development, acquisition by a public or private conservation authority is often the most appropriate action. The use of any of these conservation tools requires reliable information obtained from rigorous and systematic analysis.

The methodology for the current assessment is a refinement of previous assessments and reserve selection and design projects conducted by our research group and others. Our “three-track method,” first applied to the Klamath-Siskiyou ecoregion of northwestern California and adjacent Oregon, seeks to serve several basic goals of biological conservation:

- Representing all kinds of ecosystems, across their natural range of variation, in protected areas;

- Maintaining viable populations of all native species in natural patterns of abundance and distribution;

- Sustaining ecological and evolutionary processes within their natural ranges of variability; and

- Building a conservation network that is adaptable to environmental change.

In order to serve these goals, our methodology integrates three basic planning approaches that conservation biologists have pursued over the last several decades (albeit these approaches have usually been pursued separately rather than jointly):

- Protection of special elements—identifying, mapping, and protecting rare species occurrences (and particularly “hotspots” where occurrences are concentrated), watersheds with high biological values, imperiled natural communities, and other sites of high biodiversity value;

- Representation of habitats—inclusion of a full spectrum of habitat types (e.g., vegetation, abiotic habitats, aquatic habitats) in protected areas or other areas managed for natural values;

- Conservation of focal species—identifying and protecting key habitats of wide-ranging species and others of high ecological importance or sensitivity to disturbance by humans.

Together, these three tracks constitute a comprehensive approach to biological conservation. Integrating the results of site-selection algorithms, population models, and other quantitative approaches with qualitative data and the experience and intuition of biologists and managers, is a defensible strategy for the protection of biodiversity.

Our three-track method for selecting and designing a conservation network is an extension of the "fine filter/coarse filter" approach of The Nature Conservancy. The fine filter focuses on rare species and communities and is represented by our special elements track. The coarse filter is our second track. Also known as the representation approach, the coarse filter seeks to protect high-quality examples of all natural communities or ecosystems in a region. Especially when applied on a landscape scale, with the notion of representing all ecosystems in a region across their natural range of variation, the coarse filter is complementary to rare-species conservation. It may be especially useful for capturing species groups that have been poorly inventoried. The Nature Conservancy has estimated that 85-90% of all species can be protected by the coarse filter. Species that fall through the pores of the coarse filter—such as narrow endemics—can be protected through the fine filter.

Consideration of species with demanding spatial requirements constitutes the third track in our approach—focal species. We selected four carnivores and one ungulate as the focal species for this assessment: grizzly bear, gray wolf, wolverine, lynx, and elk. Adequate data to construct regional-scale habitat models were available for these species. Our research suggests that these species, collectively, respond to a broad range of landscape features and provide ecological indicator and umbrella species values. The GYE is especially significant in terms of focal species, as it possesses what is probably the densest elk population in the world and is the most southerly area in North America with potentially viable populations of grizzly bear, wolf, and wolverine. Moreover, the potential exists for expansion of carnivore populations from the GYE to other portions of the UWRM. Hence, our assessment places greater emphasis on focal species than most previous ecoregional or multi-criteria conservation plans.

The needs of focal species are often best considered through modeling. For species not expected to show strong area or connectivity limitations, given the relationship between their life-history characteristics (territory size, population density, dispersal ability) and current landscape condition, the optimal approach is often to select the highest quality habitat as identified by a static habitat suitability model. Species with very large area requirements or dispersal needs, however, are not adequately addressed by static models. To create a coherent regional-scale conservation strategy for these species, dynamic modeling that integrates life-history characteristics and habitat configuration (e.g., the size and spacing of habitat areas) is useful. These species usually have relatively low population density, require a large area of habitat, or do not disperse easily across the landscape matrix (e.g., developed or non-forested habitat). All of our carnivore focal species fit this description to one degree or another.

Methods

Planning Units

The building blocks of a conservation plan are the sites that are compared to one another in the conservation assessment. We used 6th-level watersheds as planning units because they are ecologically relevant and are of a convenient scale for ecoregional planning. Among other advantages, using watersheds as planning units allows site selection algorithms to represent aquatic systems as intact and connected units. Nevertheless, 6th-level watersheds had not been delineated for most of the study area. Therefore, we created pseudo (modeled)-6th-level watersheds using the BASINS function in ArcInfo GRID geographic information system (GIS) software, based on a 90 m digital elevation model. To better conform the resulting polygons to recognized watersheds, we merged them with USGS 5th-level watersheds. We eliminated polygons smaller than 2,000 ha (4942 acres; leaving the official 5th-level watershed lines intact) and further divided several large polygons to avoid potential species-area effects, which could bias the site selection algorithm. To distinguish existing protected areas from other lands, we merged the watershed polygons with USGS Gap Analysis Program (GAP) management status 1 (strictly protected) and 2 (moderately protected) polygons. This procedure resulted in 2379 planning units, ranging in size from 1 ha (2.47 acres) to 39,473 ha (97,498 acres) and averaging 4,604 ha (11,372 acres). (The smaller units were watersheds partly within existing protected areas. Only the portions of the watersheds that fell outside protected areas were considered planning units in this analysis, as we assumed that protected areas are, in fact, already protected.) GAP level 1 and 2 protected areas constitute 3.3 million hectares (8,151,000 acres), or 30%, of the 10.9 million hectare (26,933,900 acre) UWRM.

The SITES Selection Algorithm

Early conservation assessments and reserve designs depended on manual mapping to delineate sites and on simple scoring procedures to compare and prioritize sites. The large number of conservation targets and the large size and diverse types of data sets describing the targets in this study required the use of a more systematic and efficient site selection procedure. We used the site-selection software SITES (v1.0) to assemble and compare alternative portfolios of sites. SITES attempts to minimize portfolio “cost” while maximizing attainment of conservation goals in a compact set of sites. This set of objectives constitutes the “Objective Cost function:”

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

where Cost is the objective (to be minimized), Area is the number of hectares in all planning units selected for the portfolio, Species Penalty is a cost imposed for failing to meet target goals, and Boundary Length is a cost determined by the total boundary length of the portfolio.

We made numerous SITES runs, with varying quantitative goals, to determine alternative portfolios which met stated goals for the protection of target groups: local-scale imperiled species, bird species, aquatic species, and rare plant communities within the special elements track; vegetative, combined vegetative and abiotic, and aquatic habitat types within the representation track; and high-quality habitat for the five species analyzed within the focal species track.

Special Elements

We assembled element occurrence data for the study area from state heritage programs in Montana, Idaho, Wyoming, Utah, and Colorado. After excluding occurrences of species or communities last observed prior to 1982, or ranked as non-viable or non-breeding occurrences by the heritage programs, 2961 occurrences of 563 species and communities remained (Fig. E2), 416 of them for the 109 species and communities with conservation status ranks of G1 (critically imperiled globally) or G2 (imperiled globally). We divided the occurrence data into four target groups for separate SITES analyses: local-scale species (class 1 targets in Appendix A), bird species (class 2), coarse- and regional-scale aquatic species (class 4), and plant communities (class 5). We set goals for 100% capture of the G1 and G2 occurrences in all target groups and capture of at least 10 occurrences of lower conservation status. A SITES portfolio had to meet these goals or was penalized as part of the cost function.

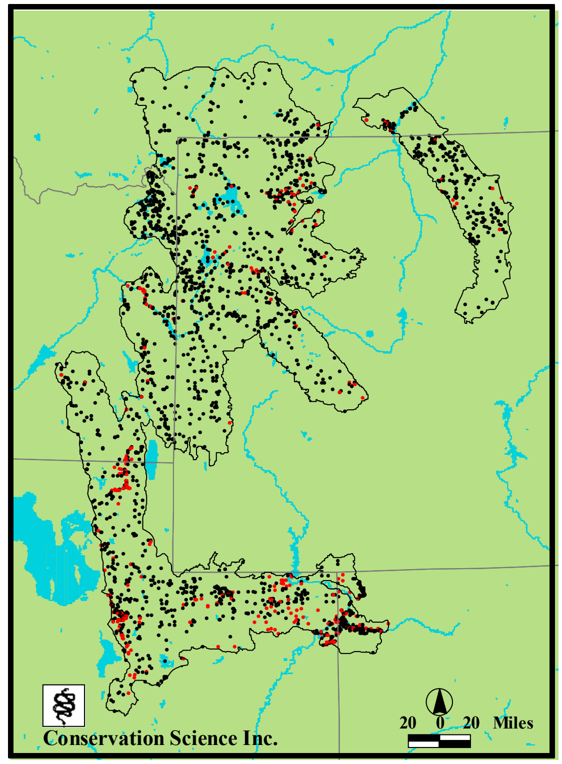

Figure E2. UWRM natural heritage data. G1 and G2 in red, others black

We made10 repeat runs in SITES for each special elements target group, using the "sum runs" option. Each run consisted of one million iterations, the number of attempts the algorithm makes to find a solution. Output from the sum runs includes an indication of how many times each planning unit was included in the 10 different portfolios, as well as the "best" (lowest cost) portfolio solution of the 10. The number of times planning units were selected for in these runs was used in determining the irreplaceability of megasites in our preferred alternative portfolio (see below).

Representation

The Nature Conservancy (TNC) recommends the identification of "ecological systems"—dynamic spatial assemblages of ecological communities—that represent the entire range of ecosystems found within an ecoregion. The terrestrial ecological systems of the UWRM have not been classified. Hence, we used a combination of vegetation types mapped by the state GAP programs and a new classification of physical (i.e., abiotic or geoclimatic) habitats in an effort to represent terrestrial ecological communities across environmental gradients. Representing a broad spectrum of geoclimatic habitats and associated vegetation—ideally along intact environmental gradients—is a strategy for facilitating the shifts in distribution that species will need to make in response to climate change. For aquatic communities, we used the aquatic ecological systems classification developed by Mary Lammert, Aquatic Ecologist with TNC's Freshwater Initiative. As with special elements, we used the sum runs option in SITES to determine how frequently planning units were selected for portfolio solutions to represent terrestrial and aquatic habitat types, then used that information in determining our preferred alternative portfolio megasite irreplaceability scores.

The GAP program has mapped current vegetation types in the five states included in the project. We merged the vegetation maps into a single map that includes 44 vegetation types in the study area (Fig. E3). These vegetation types correspond generally to the alliance level of classification hierarchy. We performed a gap analysis to judge how well the existing system of protected areas represents regional vegetation types. We used SITES to develop portfolios of planning units that would protect at least 35% of the area of each wetland vegetation type (lowland riparian, mountain riparian, water, wetland, wet meadow) and 25% of all other types, with the justification that wetland types are of generally higher biological value in the region.

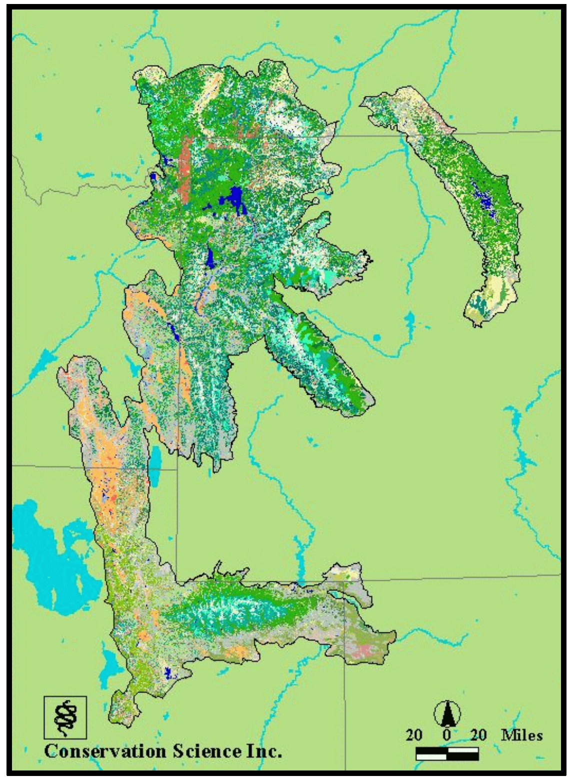

Figure E3. UWRM Gap Analysis Program vegetation types.

We performed the classification of physical habitats in ArcInfo GIS using the major components of climate variation in the study area: 1) mean annual precipitation; 2) spring precipitation; 3) mean annual low temperature; 4) mean annual high temperature; and 5) the difference between winter mean low temperature and summer mean high temperature. We also used mean annual growing degree days in the classification. Soil depth, water-holdin g capacity, and organic carbon content were all derived from the STATSGO soils database. The nine climate and soils variables were used in a cluster analysis, which identified 43 physical habitat types in the study region (Fig. E4). We combined GAP vegetation and physical habitat types, then used SITES to develop portfolios that would protect at least 10% of the area of each combined type.

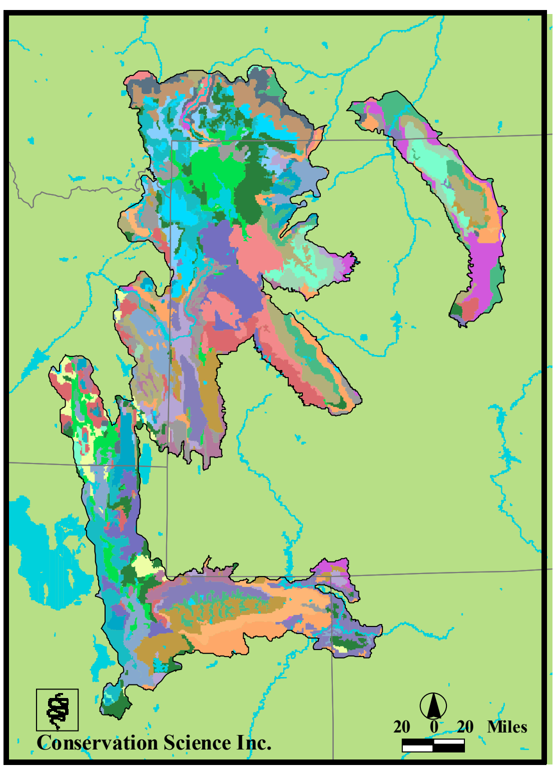

Figure E4. UWRM physical habitat types.

We applied two levels of aquatic habitat classification: 1) aquatic macrohabitats, identified at the stream reach level; and 2) aquatic ecological systems, identified at the watershed to basin level. Both classifications utilize four components: 1) stream size (headwater to large river); 2) elevation (low to alpine); 3) stream gradient (low to very steep); and dominant geology (coarse, porous, nonporous). Aquatic macrohabitats were classified by specific portions of the range of each of the four components, e.g., “very steep alpine headwater in coarse geology.” Aquatic ecological systems, being aggregations of macrohabitats, represent a greater range of component gradients, e.g., “alpine, includes moderate and low gradients, headwater and creek, granitic or volcanic.” We integrated aquatic ecosystems and nested macrohabitats as combined inputs to SITES, and set goals of representing at least 35% of each combined aquatic habitat type.

Focal Species

We used GIS data on species distribution and habitat characteristics to construct new static habitat suitability models for our selected focal species in the region. These results were then compared with those from dynamic models that placed regional population dynamics within a larger multi-regional context. Species distribution data included sightings records of lynx and wolverine, grizzly bear radiotelemetry locations, and the boundaries of wolf pack territories. Habitat data included vegetation, satellite imagery metrics, topography, climate, and human-impact related variables (e.g., road density). We used multiple logistic regression to compare habitat variables at telemetry or sighting locations with those at random points. Predicted habitat values can be seen as map-based hypotheses subject to refinement and validation by future survey data.

We performed population viability analyses using the program PATCH. This program links the survival and fecundity of individual animals to GIS data on mortality risk and habitat productivity measured at the location of the individual or pack territory. The model tracks the population through time as individuals are born, disperse and die, predicting population size, time to extinction, and migration and recolonization rates. The model allows the landscape to change through time. This permits the user to quantify the consequences of landscape change for population viability, examine changes in vital rates and occupancy patterns that might result from habitat loss or fragmentation, and identify source and sink habitats within a landscape.

The landscape change scenarios used estimates of potential change in human-associated impact factors (e.g., roads and human population) during the period 2000-2025 given increased development on either private and non-protected public lands or on private lands only. Data layers from the focal species analysis were incorporated as additional targets in the SITES portfolio selection. We then compared alternative SITES solutions with results from the PATCH model to assess whether the portfolios ensured population viability and if not, what additional areas were suggested by the PATCH model.

Expert Assessment

Quantitative data on which to evaluate conservation options are always limited. We sought to apply rigorous, objective measures of conservation value whenever possible, recognizing that a quantitative assessment would need to be supplemented by expert opinion. We chose a combined approach of one-on-one interviews during early phases of this work, followed by workshops to evaluate the draft results.

Expert opinion was sought to provide validation of element occurrence data from heritage programs and other sources and to expand the overall knowledge base. George Wuerthner identified a wide range of experts on various aspects of the UWRM ecoregion, then visited and interviewed these experts. Interviews were conducted during late 1999-2000 throughout the ecoregion. People contacted included federal and state agency biologists, university faculty, staff of environmental groups, and others with knowledge of the ecoregion's biological attributes. Interviews included discussion of the person's qualifications and knowledge of the ecoregion, habitat conditions of the lands in question, status of rare or sensitive species, threats, and any monitoring, surveys, or management being implemented for the species or communities concerned.

Immediately after our draft report was produced, our team participated in two workshops to present our results, evaluate alternative portfolios, and identify the next steps for conservation of priority areas. The first workshop was organized by the Greater Yellowstone Coalition and held April 5-6, 2001, in Bozeman, Montana. This workshop concentrated on the GYE. The second workshop was organized by the Wyoming Field Office of The Nature Conservancy and held April 9-10, 2001 in Lander, Wyoming. This workshop examined the entire UWRM ecoregion.

Megasite Ranking

We aggregated planning units into "megasites" for purposes of evaluation and priority setting. Megasites comprised generally contiguous planning units selected as the best (i.e., "best runs" with lowest cost) of the SITES sum runs. Other planning units were evaluated as potential connectivity zones linking megasites, but these units were not included in the portfolio per se. Boundaries of 4th level watersheds and other natural features were used to delineate boundaries between adjacent megasites. Hence, these larger sites are areas that "make sense" in terms of geography, land ownership, or other factors that must be considered in the process of implementing a conservation plan. We strove to keep the number of megasites reasonably low in order to allow comparative scoring and priority-setting.

We relied on a key concept in conservation planning—irreplaceability—to prioritize megasites. Irreplaceability provides a quantitative measure of the relative contribution different areas make to reaching conservation goals. A site with an irreplaceability value of 100 for a particular class of targets is essential to meeting a particular goal; if that site is destroyed, the goal cannot be attained. An example might be a site that holds the only known occurrence of a species in the ecoregion. A site with an irreplaceability value of 0 has essentially infinite replacements.

Because our assessment considers multiple values of megasites and attempts to achieve a broad set of conservation goals, we assigned irreplaceability values to megasites based on 9 criteria:

1) Contribution to the goal of protecting at least 10 viable occurrences (or 100% for G1/G2 species) of all imperiled, local-scale (class 1) species in the ecoregion.

2) Contribution to the goal of protecting at least 10 viable occurrences (or 100% for G1/G2 species) of vulnerable and declining (class 2) bird species in the ecoregion.

3) Contribution to the goal of protecting habitat capable of supporting 50-70% of the population of each focal species (class 3) that currently could be supported in the ecoregion, as identified by habitat suitability modeling (i.e., 50% for elk, 70% for carnivores).

4) Contribution to the goal of maintaining viable populations (regionally and inter-regionally) of focal species over time, as determined by the PATCH dynamic model. Scores were an average of predicted lambda (population growth rate) values for grizzly bear, wolf, and wolverine, weighted by the likelihood that a site was occupied by the species.

5) Contribution to the goal of protecting at least 10 (or 100% for G1/G2 species) viable occurrences of coarse-scale and regional-scale aquatic species (class 4) in the eco region.

6) Contribution to the goal of protecting 100% of all viable occurrences of G1/G2 plant communities and at least 10 of the occurrences of other plant communities of high conservation interest (class 5) in the ecoregion.

7) Contribution to the goal of representing at least 35% of the area of each wetland vegetation type and at least 25% of the area of each other vegetation type in the ecoregion.

8) Contribution to the goal of representing at least 10% of the area of each combined vegetation and abiotic (geoclimatic) habitat type in the ecoregion.

9) Contribution to the goal of representing at least 35% of the length of each aquatic (stream) habitat type in the ecoregion.

Each megasite was scored 0-10 for each of the 9 criteria. For criteria 1-3 and 5-9, the number of times (out of 10) individual planning units were selected in SITES sum runs were averaged and the area-weighted mean used as the score for each megasite. For criterion 4, entire megasites were scored as units. A total irreplaceability score was calculated for each megasite by summing the scores from the 9 criteria and rescaling the sums to range from approximately 1 to 100.

Another key consideration in conservation planning is threat or vulnerability. Based on expert opinion about the threats faced by each megasite, and taking into consideration quantitative threat data (e.g., human population growth, development trends), we assigned a vulnerability score of 0-100 to each megasite. Preliminary vulnerability scores were revised by participants in the workshop in Lander and those revised scores were rescaled to range from approximately 1 to 100. Megasites were then plotted on a graph of irreplaceability (y-axis) versus vulnerability (x-axis) and the graph divided into four quadrants. The upper right quadrant, which includes megasites with high irreplaceability and high vulnerability, comprises the highest priority sites for conservation. This top tier of megasites is followed by the upper left and lower right quadrants (2nd and 3rd tiers, which could be ordered differently depending on needs of planners), and finally, by the lower left quadrant, comprising megasites that are relatively replaceable and face less severe threats. Within quadrants, megasites were ranked for conservation priority using the sum of their irreplaceability and vulnerability scores.

Results and Discussion

Proposed Portfolio

Our proposed portfolio (Fig. E5) is based on SITES best runs results that included all components of the three tracks (special elements, representation, and focal species). The 43 megasites in the portfolio range in size from18,332 to 1,225,041 acres (average size 235,485 acres) and total 10,125,847 acres (37% of the UWRM). Private lands constitute 34% (3.4 million acres) of the total portfolio area. The connectivity zones shown in Fig. E5 are designed to link megasites into a functional network. These 62 zones, based largely on elk winter habitat and topographic features, include 106 planning units and constitute 1,313,037 acres. Although not part of the portfolio per se, we recommend that development and other sources of fragmentation be minimized within these zones until detailed studies of wildlife movement allow critical movement routes to be identified.

Our proposed portfolio, if fully protected and combined with existing protected areas (totaling 8,151,000 acres), would bring the total protected area in the UWRM to18,277,000 acres, nearly 68% of the ecoregion. That protected areas network would encompass nearly 86% of special element occurrences, focal species habitat, and terrestrial and aquatic ecological systems within the study area (Table E1). As shown in the "Δ" column in Table E1, the proposed portfolio—if fully protected—would cover 37% more of the ecoregion than the current reserve network. For that 37% increment, there is a considerable "bang for the buck" for many elements—for example, a 58% increase (to 100%) in coverage of G1/G2 species, a 51%

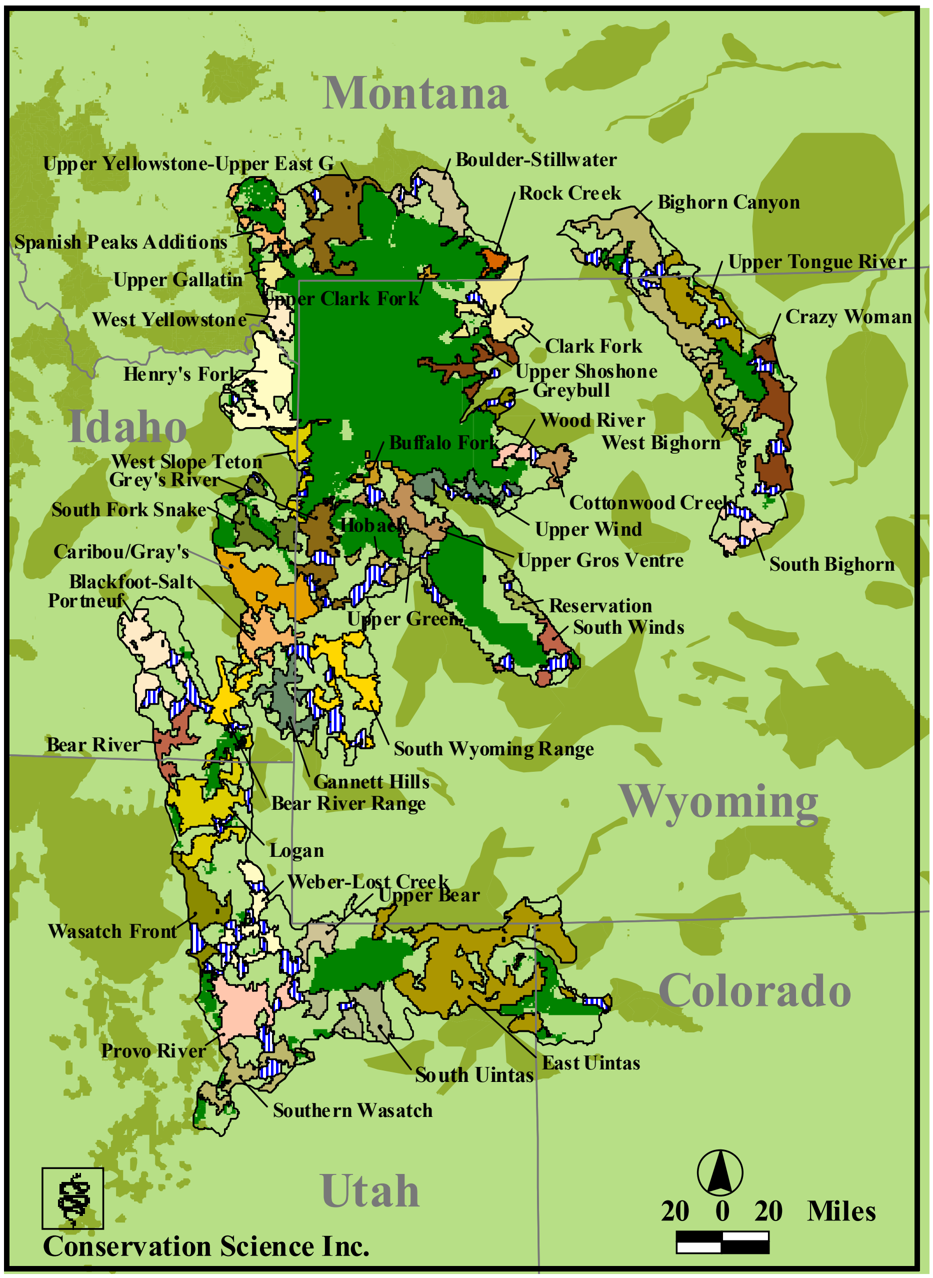

Figure E6. Proposed portfolio of conservation sites. Existing protected areas dark green, proposed connectivity zones hatched blue, adjacent ecoregion portfolios in background.

increase for all special elements combined, and a 57% increase for representation of ecological systems (vegetation, aquatic habitats, and vegetation and physical habitats combined).

Table E1. UWRM portfolio conservation target protection increases.

	Current %	Plus Quad1	Plus Quad2	Plus Quad3	Plus Quad4	Total Δ (%)
Protected Area	30.0	38.1	48.5	64.5	67.5	+37.5
Special Elements						
All G1-G2	41.8	51.7	60.3	98.8	100	+58.2
Class 1–Local-Scale Species	42.7	51.7	65.8	89.0	91.3	+48.6
Class 2–Birds	30.1	61.5	70.7	85.9	86.5	+56.4
Class 4–Fish	26.7	29.2	35.4	60.9	61.7	+35.0
Class 5–Plant Communities	41.7	73.0	92.5	97.4	100	+58.3
Special Elements Average	36.6	53.2	64.9	86.4	87.9	+51.3
Focal Species Resources						
Elk Winter Range	14.0	22.4	36.5	57.4	61.7	+47.7
Grizzly	91.6	92.5	94.4	96.8	97.3	+5.7
Lynx	36.9	45.0	56.5	67.8	70.5	+33.4
Wolf	71.9	74.4	79.9	86.0	87.1	+15.2
Wolverine	40.1	46.9	56.0	68.5	70.6	+30.5
Focal Species Average	50.9	56.2	64.7	75.3	77.4	+26.5
Representation						
$\geq$ 25-35%–Vegetation Types	38.6	68.2	72.3	100	100	+61.4
$\geq$ 10%–Vegetation/Physical Habitat Types	44.7	58.5	71.9	89.2	93.9	+49.2
$\geq$ 35%–Aquatic Types	36.5	56.3	79.0	93.3	96.7	+60.2
Representation Average	39.9	61.0	74.4	94.2	96.9	+57.0
Total Average	42.9	56.3	67.0	84.7	85.9	+43.0

Focal Species Considerations

Focal species do not receive as great a benefit from our proposed portfolio as special elements or ecological systems—only elk winter habitat would increase by more than the 37% in total area that would result from protecting the entire portfolio of megasites. For grizzly bear and wolf, only 5.7% and 15.2%, respectively, more habitat would be protected. This relatively low added value reflects the fact that these carnivores find their highest quality habitat within existing protected areas—especially Yellowstone National Park and adjacent wilderness areas—which provide the low road density and other components of habitat security these animals require. Nevertheless, as discussed below, increasing the protected areas network in the UWRM would help mitigate against the loss of habitat value that will occur as human population and associated developments increase in the region over the next several decades. Protection of roadless areas is especially important for these species.

The grizzly bear habitat suitability model showed a negative association of bears with roads, and a positive association with sloping terrain, elk winter range, and protected areas. The interaction of roads and trails with the wilderness management class has become more strongly negative with time, perhaps reflecting increased hunter-associated mortality.

The wolf model, though similar to that for the grizzly bear, differs in the strong negative association with slopes of above 20 degrees. The wolverine model also shows a positive association with wilderness and especially parks, making it similar to the models for the grizzly bear and wolf. Potential effects of adding the non-wilderness RARE II roadless areas to a protected areas network suggest that substantial areas of the southern and northwestern GYE portion of the ecoregion show potential for enhancing carnivore populations under this scenario.

The UWRM region is predicted to lose a substantial percentage of its carrying capacity for carnivores in the next 25 years if current trends continue. The predicted loss ranges from 13.0% for the wolverine to 23.1% for both the wolf and the grizzly bear. If no new road construction occurs on public lands, the loss is reduced by approximately 50%, e.g., to 11.9% for the grizzly bear and 13.0% for the wolf. Although the presence of large core areas such as Yellowstone National Park buffers populations from complete extirpation, changing landscape conditions have strong impacts on both abundance and distribution of these and other carnivore species.

Under optimistic assumptions as to demographic rates under current landscape conditions, the PATCH model predicts that areas capable of supporting grizzly bears encompass most of the public lands core of the GYE and some private lands along the western edge of the Bighorn basin. Wolves could potentially occupy a larger area that is contiguous with the central Idaho population.

Under pessimistic future conditions the core area of the GYE remains occupied and is a strong source for grizzly bears, but it is no longer able to support the large areas of peripheral distribution. This core area is already surrounded by a ring of strong sink habitat, and this ring of sinks will intensify with increasing human population and road-building (Fig. E6). These forces will eliminate many non-core areas of the GYE as potential habitat. If habitat degradation does not occur on public lands—i.e., if roadless areas are protected—the reduction in demographic potential is not as severe. This contrast is especially evident in areas that are peninsular extensions of habitat from the core GYE.

The GYE grizzly bear population appears to be demographically isolated from other regions under most plausible landscape scenarios. This may pose long-term dangers from genetic isolation. Nevertheless, the dramatic impact of future landscape change on the potential distribution and size of the region's bear population suggest that the highest priority should be to prevent loss of connectivity within the region itself by protecting these at-risk areas. An enlarged recovery zone and improved roadless area management policy on public lands, when coupled with conservation strategies on private lands identified as critical population sinks, could potentially prevent much of this population decline and loss of habitat.

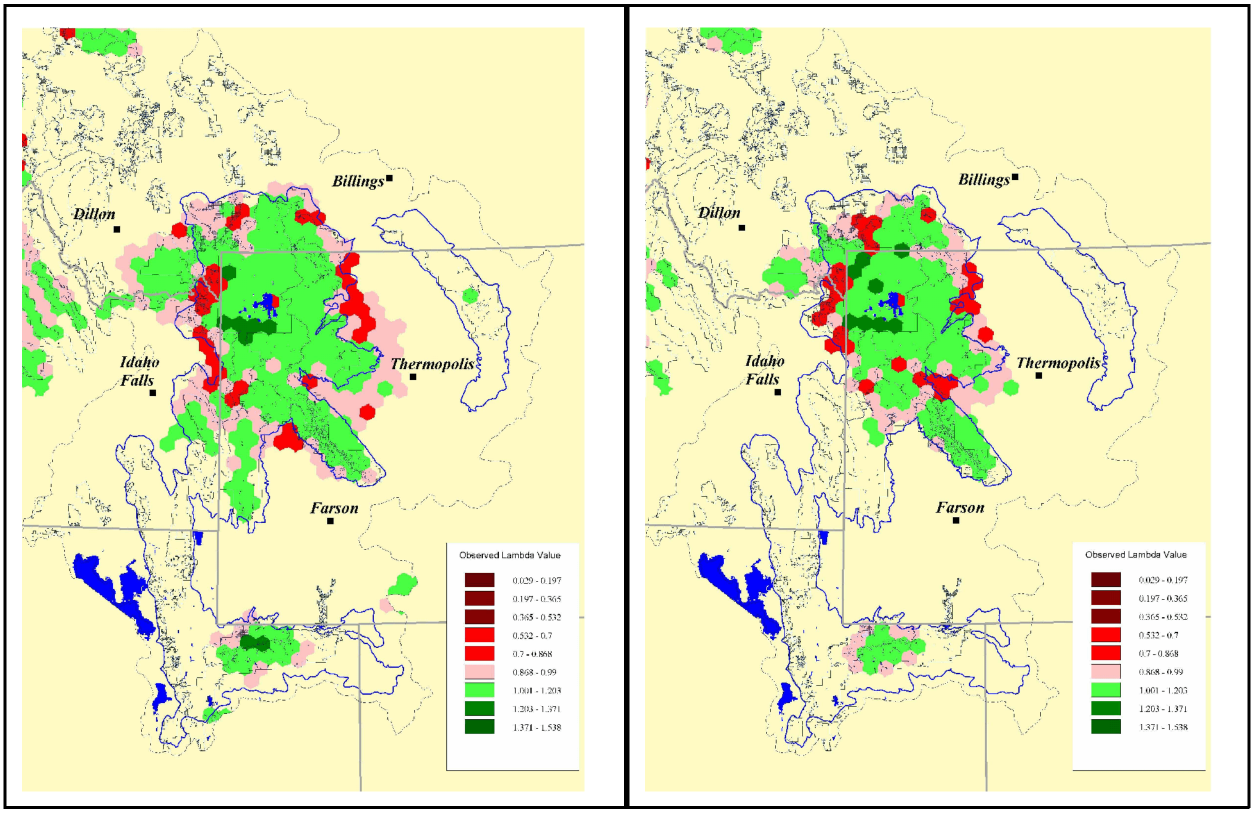

Fig. E6. Demographic potential and potential distribution of grizzly bears under current (a) and future (b) landscape conditions (scenario 2 - road development on both private and public lands) as predicted by the PATCH model. Sink areas are shown in red and source areas in green.

Because the wolf can inhabit semi-developed habitat outside the core GYE, it will be more dramatically affected by future development in those areas. Under current conditions the GYE wolf population should be able to form a connected metapopulation encompassing most public lands and some private lands in the GYE and adjacent regions. Under future scenarios, outlying areas become sink habitats for wolves, and although connectivity is maintained to central Idaho, the GYE becomes isolated from more distant populations in the Northern Continental Divide Ecosystem. If road development is limited on public lands, the viability of peripheral populations and connectivity to central Idaho is enhanced. Because demographic rescue from core areas would be important in sustaining wolves in matrix habitat, high priority should be given to maintaining habitat continuity between the GYE and central Idaho populations. A secondary priority would be to maintain connections to the south, for instance to the Uintas, where suitable habitat for wolves exists and may be colonized naturally.

For the lynx, relatively low levels of population cycling are predicted to greatly increase extinction risk if the GYE and other suitable areas within the UWRM are isolated from boreal lynx populations. Further range contraction is predicted for all carnivore species without coordinated regional planning for habitat restoration.

We evaluated elk winter range, as delineated by species experts, as to viability based on road density and other human-impact factors. Areas of wintering habitat with high potential viability (low road density) on private lands were identified for inclusion in conservation portfolios. The elk winter range predictive model shows a positive association with well-vegetated areas that are somewhat sloping, southwest aspects. On a regional scale, these areas (Fig. E7) do not overlap strongly with high quality habitat for the large carnivores, largely due to the human-associated factors that restrict carnivore distribution more than ungulate distribution.

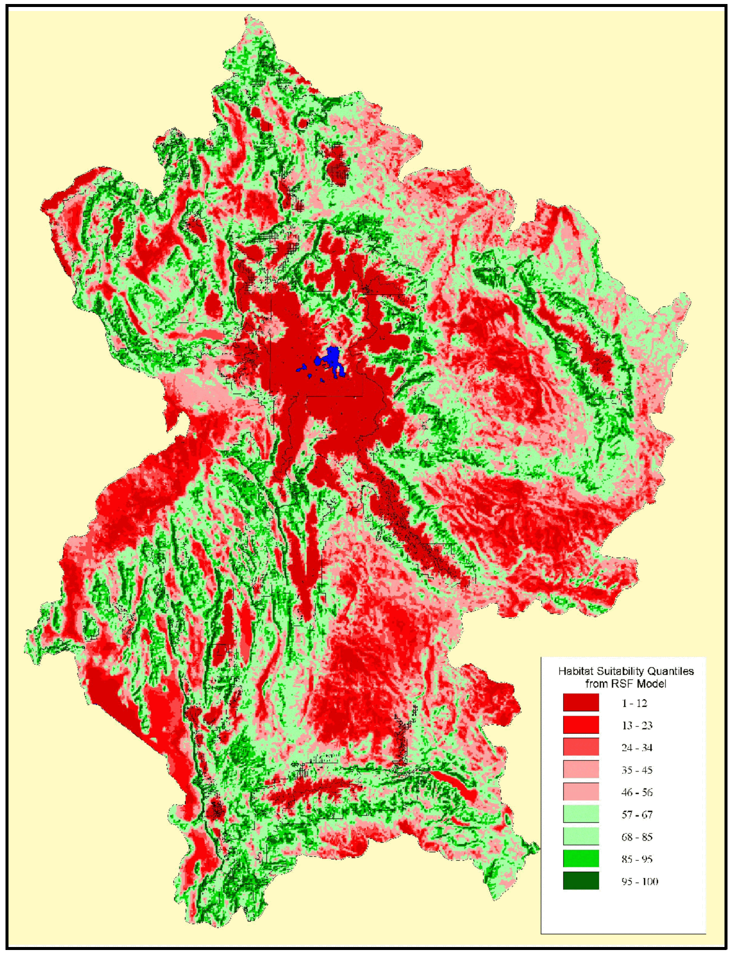

Fig. E7. Results of a logistic regression model predicting relative suitability as elk wintering habitat.

By linking demography to mapped habitat characteristics, our analysis helps reveal the regional mechanisms driving population viability as the UWRM changes over the next quarter century. The results suggest that despite the presence of large protected areas in the region, it will be challenging to conserve carnivores in the GYE, or the UWRM as a whole, as human populations grow. Many of the carnivore populations in the region are on the periphery of their range due to climatic or historical factors, or both, and, unlike more northern populations, cannot expect a large "rescue effect" from surrounding regions. As these carnivore populations rebound from historical eradication efforts, they will find their habitat options increasingly foreclosed by the rate of landscape change.

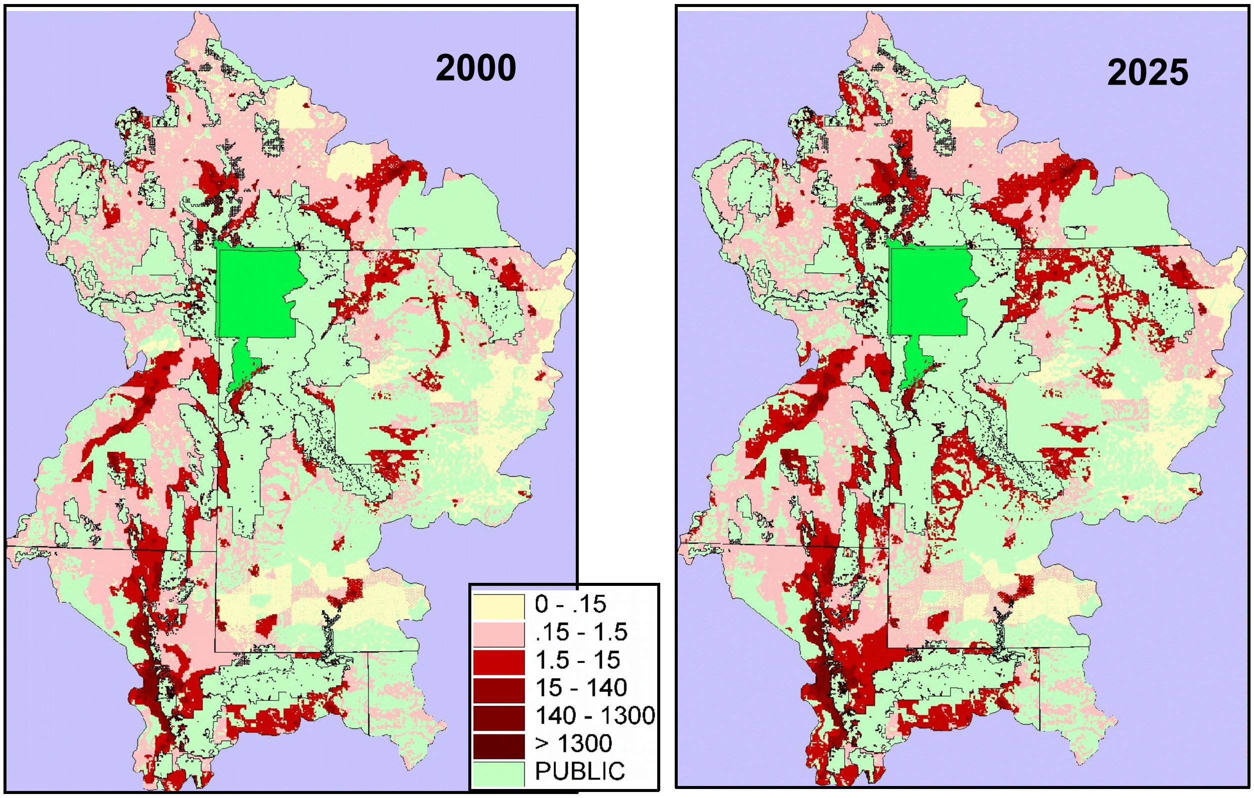

Figure E8. Current and predicted housing density per square kilometer (data from Theobald 2001)

The GYE is unique in the western United States in that large core refugia lie in close proximity to rapidly growing human populations (Fig. E8). Currently, the core refugia of the park and adjacent wilderness areas can support carnivore populations in outlying areas. Because these outlying areas may not yet be occupied by expanding carnivore populations, they may not receive adequate conservation focus and may be more subject to competing land uses such as grazing than are areas within the core GYE. If current trends continue, a ring of development will increasingly surround the core with sink habitat, isolating it from the “arms and legs” of the ecoregion and weakening its ability to sustain carnivores in those outlying areas.

Given the contrasts between species, building a conservation strategy that combines priority areas for all focal species is challenging. Areas of high value for multiple species must combine both biological productivity and security from human impacts. Such areas (e.g., undeveloped riparian areas) are scarce in the UWRM and tend to be highly threatened by development. Comparison of the results from our alternate future scenarios suggests that only about half of the loss in carnivore carrying capacity is linked to development on public lands. Even for wide-ranging species such as the grizzly bear that are closely associated with wilderness, conservation planning must address entire landscape mosaics of public and private lands.

Megasite Ranking

Megasite irreplaceability scores ranged from 7.5 to 94.4 (mean: 49.7), and vulnerability scores from 1.5 to 98.5 (mean: 52.2). Our irreplaceability vs. vulnerability prioritization resulted in 9 megasites totaling 2.2 million acres in the high irreplaceability-high vulnerability quadrant 1, giving them the highest priority for conservation action (Figs. E9, E10). Twelve megasites in quadrant 2 (high irreplaceability-low vulnerability, medium priority) cover 2.8 million acres; 13 megasites in quadrant 3 (low irreplaceability-high vulnerability, medium priority) cover 4.4 million acres; and 9 megasites in quadrant 4 (low irreplaceability-low vulnerability, lower priority) cover 0.8 million acres.

To compile an overall ranking of megasite conservation priority, we first combined their irreplaceability and vulnerability scores. We then ordered them within quadrants according to combined scores (Table E2).

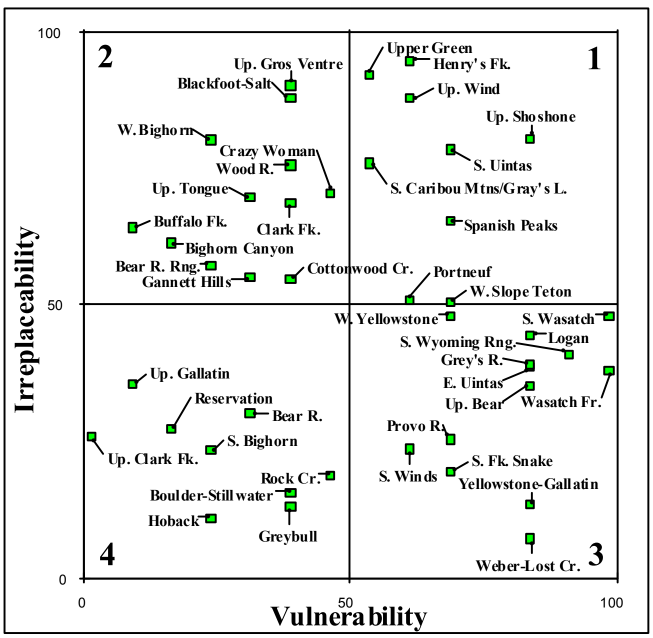

Figure E9. Megasite irreplaceability and vulnerability, with quadrants.

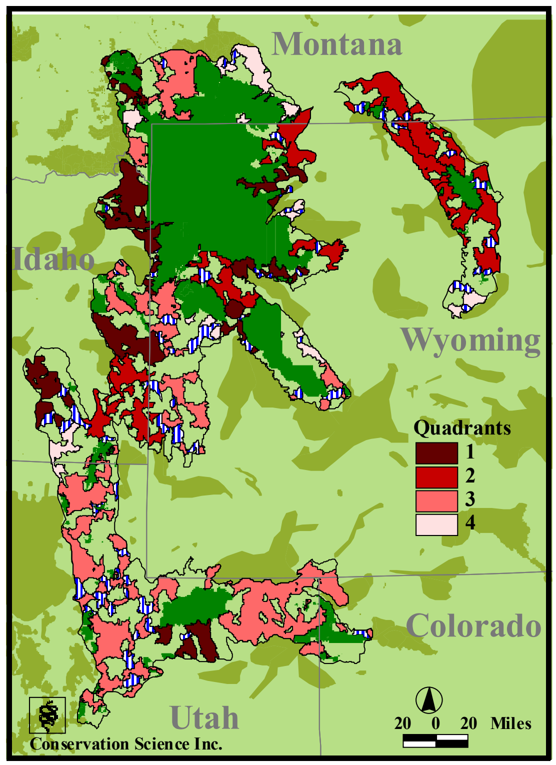

Figure E10. Megasite quadrants, connectivity zones hashed blue.

Table E2. Megasites list. Sites within each quadrant are ordered by their combined irreplaceabiilty and vulnerability scores.

Rank	Name	Irreplaceability	Vulnerability	Irreplaceability + Vulnerability	Quadrant	Acres
1	Upper Shoshone	80.5	83.6	164.1	1	170388
2	Henry's Fork	94.4	61.2	155.6	1	450148
3	Upper Wind	87.7	61.2	148.9	1	167651
4	South Uintas	78.4	68.7	147.1	1	272142
5	Upper Green	92.1	53.7	145.8	1	127044
6	Spanish Peaks Additions	65.4	68.7	134.1	1	129715
7	S. Caribou Mtns/Gray's Lake	75.8	53.7	129.5	1	392377
8	West Slope Teton	50.3	68.7	119.0	1	148776
9	Portneuf	50.8	61.2	112.0	1	317620
10	Upper Gros Ventre	90.1	38.8	128.9	2	214156
11	Blackfoot-Salt	87.8	38.8	126.6	2	207700
12	Crazy Woman	70.6	46.3	116.9	2	328075
13	Wood River	75.5	38.8	114.3	2	59149
14	Clark Fork	68.6	38.8	107.4	2	298774
15	West Bighorn	80.1	23.9	104.0	2	182284
16	Upper Tongue	69.8	31.3	101.1	2	332385
17	Cottonwood Creek	54.6	38.8	93.4	2	98597
18	Gannett Hills	55.1	31.3	86.4	2	219983
19	Bear River Range	57.2	23.9	81.1	2	182908
20	Bighorn Canyon	61.4	16.4	77.8	2	560287
21	Buffalo Fork	64.0	9.0	73.0	2	76479
22	South Wasatch	48.1	98.5	146.6	3	255852
23	Wasatch Front	38.2	98.5	136.7	3	255344
24	South Wyoming Range	40.9	91.0	131.9	3	301036
25	Logan	44.6	83.6	128.2	3	477824
26	Grey's River	39.3	83.6	122.9	3	271987
27	East Uintas	38.8	83.6	122.4	3	1225041
28	Upper Bear	35.2	83.6	118.8	3	113000
29	West Yellowstone	48.0	68.7	116.7	3	108986
30	Up. Yellowstone-Up. E. Gallatin	13.6	83.6	97.2	3	486501
31	Provo River	25.5	68.7	94.2	3	348631
32	Weber-Lost Creek	7.5	83.6	91.1	3	202483
33	South Fork Snake	19.6	68.7	88.3	3	222651
34	South Winds	23.7	61.2	84.9	3	107554
35	Rock Creek	18.9	46.3	65.2	4	47861
36	Bear River	30.3	31.3	61.6	4	156986
37	Boulder-Stillwater	15.8	38.8	54.6	4	240212
38	Greybull	13.3	38.8	52.1	4	48022
39	South Bighorns	23.5	23.9	47.4	4	99998
40	Upper Gallatin	35.7	9.0	44.7	4	69249
41	Reservation	27.6	16.4	44.0	4	71440
42	Hoback	11.3	23.9	35.2	4	60219
43	Upper Clark Fork	25.9	1.5	27.4	4	18332

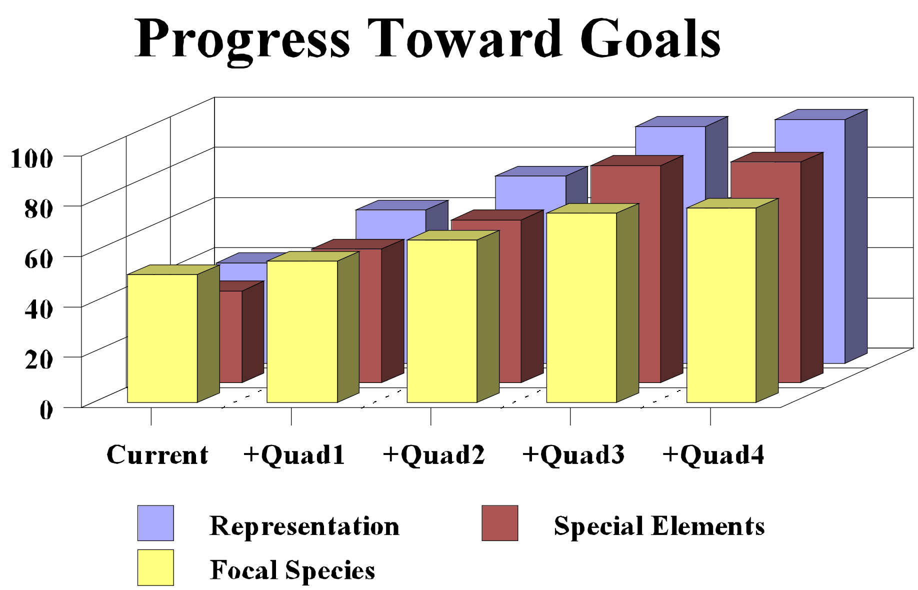

Figure E11. Increases in achieving conservation goals by incrementally protecting megasites in the four quadrants of the irreplaceability vs. vulnerability chart (Fig. E9).

Progress toward conservation goals can be achieved most efficiently by protecting first the highest priority megasites (quadrant 1), then the medium priority megasites (quadrants 2 and 3), and finally the lower priority megasites (quadrant 4) (Fig.E11). The greatest incremental gains are achieved by protecting the 9 megasites in quadrant 1, resulting in an average increase of over 14% for the three tracks (42.9% currently to 56.3%). Protecting the 12 megasites from quadrant 2 increases average protection for the three tracks another 11%, to 67%. Protecting the 13 megasites in quadrant 3 increases average protection to 84.7%, and protecting the 9 megasites in quadrant 4 results in 85.9% average protection for the three tracks.

In the real world, protection opportunities will not arise in an orderly sequence that corresponds to science-based priorities. For example, megasites in quadrants 2 or 3 may become available for protection before megasites in quadrant 1; if not protected quickly, some of these sites may be converted to subdivisions. Yet funds, or political capital, spent protecting these sites may preclude opportunities for protecting biologically more significant sites in the future.

What is the optimal course of action under such circumstances? We suggest that conservationists implement an informed opportunism, taking advantage of many conservation openings as they arise, but with explicit recognition of the trade-offs involved. Sometimes it will be better to act and other times to wait. Systematic conservation planning allows the effects of trade-offs to be quantified and considered in a biologically meaningful way. With information made transparent and explicit, decision-makers will be able to take actions which, we hope, are scientifically defensible and result in the most biodiversity conserved.

ACKNOWLEDGMENTS

This report, although chiefly representing the labor of its four authors, could not have been produced without the financial, technical, scientific, and moral support of many individuals and organizations. The Greater Yellowstone Ecosystem assessment was funded by the Greater Yellowstone Coalition, with assistance from The Nature Conservancy, the Doris Duke Foundation, and others. Michael Scott and Dennis Glick of the Greater Yellowstone Coalition were instrumental in making this study possible. Additional work on the Utah-Wyoming Rocky Mountains Ecoregion was funded by the Wyoming Office of The Nature Conservancy, and was made possible by Jerry Freilich. After Jerry Freilich's departure from TNC, Holly Copeland was our liaison with TNC and enabled us to complete this assessment efficiently. Mary Lammert, aquatic ecologist with TNCs Freshwater Initiative, kindly assumed and efficiently executed the considerable task of constructing the aquatic habitat classification, as well as providing helpful advice on integrating it into our study.

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INTRODUCTION

This report presents the results of a conservation assessment of the Utah-Wyoming Rocky Mountains Ecoregion (UWRM). It is meant to provide the basis for The Nature Conservancy's (TNC's) ecoregional conservation planning in the region and as part of the foundation for site-level planning. Both are ongoing processes. Hence, conservation planning is iterative; there is never really a "final plan." As data, knowledge, scientific theories, technology, threats, and opportunities change over time, a conservation plan must also change. The plan must be dynamic and responsive to the current situation, never set in stone.

The work that went into this report represents two overlapping projects. The first, funded by the Greater Yellowstone Coalition with assistance from The Nature Conservancy, covers the Greater Yellowstone Ecosystem (GYE). Just as that project was beginning, The Nature Conservancy (Wyoming office) decided to expand the project to include all of the UWRM ecoregion, which overlaps the GYE and also includes the Bighorn, Uinta, and Wasatch ranges. A report to the Greater Yellowstone Coalition, containing much of the same text as this report but adjusted to the different boundaries and representing a slightly different methodology, was prepared just prior to the completion of this report.

In this introductory section, we review the process of regional conservation planning and the background and objectives of this particular assessment. We then provide an overview of the UWRM, document our methodology, present the results, and discuss their implications. Our results include a portfolio of "megasites" throughout the ecoregion that, if protected or managed sustainably, will contribute to meeting conservation goals. We also provide a prioritization of megasites based on their biological values ("irreplaceability") and their vulnerability to degradation.

Regional Conservation Planning

Conservation planning on a regional scale has become the standard approach for organizations and agencies worldwide interested in the conservation of biodiversity. Whereas much of recent conservation history in North America has been dominated by actions often described as "piecemeal," "species-by-species," or "site-by-site," in large part stimulated by the requirements of such legislation as the U.S. Endangered Species Act (Noss et al. 1997), conservationists today focus increasingly on ecosystems, landscapes, and ecoregions. Species are not forgotten as the spatial and temporal scale of conservation broadens; indeed, species are often the best indicators of the status of ecosystems and are essential in answering questions about how the configuration of habitats across the landscape affects biodiversity over time (Noss 1990, Lambeck 1997, Carroll et al. 2000). Species conservation is no longer piecemeal, however. The conservation of individual species is now interpreted within the broader context of maintaining the structure, function, and composition of ecosystems within a natural or historic range of variability (Franklin et al. 1981, Landres et al. 1999, Swetnam et al. 1999). Hence, conservation today takes seriously the fundamental—but oft-forgotten—purpose of the U.S. Endangered Species Act: "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved.” Moreover, modern conservation seeks to conserve species and other elements of biodiversity before they become threatened or endangered.

Regional conservation planning, as normally pursued today, differs from conventional land-use planning in that regions are defined ecologically rather than politically (Noss and Cooperrider 1994). The GYE was first defined by John and Frank Craighead as an area large enough to sustain (based on knowledge of the time) the disjunct Yellowstone population of grizzly bears. That definition has expanded to encompass other qualities of the ecosystem, including intact watersheds and mountain ranges. Many conservation groups, in North America and elsewhere, base their planning on the boundaries of ecoregions, large areas distinguished by similarities in climate, landform, soils, vegetation, and natural processes (Dinerstein et al. 1995, Bailey 1998, Ricketts et al. 1999, Groves et al. 2000). Such ecoregions regularly overlap state and national boundaries. In 1996 The Nature Conservancy initiated its approach to ecoregional planning in the United States, drawing on experience from ad hoc regional conservation plans nationwide. Shortly thereafter, World Wildlife Fund, working with a number of experts, provided a conservation assessment of the ecoregions of the United States and Canada (Ricketts et al. 1999), one of many assessments the organization has undertaken worldwide. Meanwhile, since 1991 The Wildlands Project and cooperating groups have been developing regional conservation plans and reserve network designs across the United States, Mexico, and Canada, drawing on prototypes developed earlier (e.g., Noss 1987a, 1993). One of the largest regional conservation initiatives affiliated with The Wildlands Project is the Yellowstone to Yukon project, which involves a broad assortment of conservation groups and other stakeholders across this vast region.

A fundamental quality of regional conservation planning is that it is systematic. As described by Margules and Pressey (2000), systematic conservation planning is superior in many ways to opportunistic or politically-biased planning and has several key attributes:1) it requires clear choices about the features to be used as surrogates for overall biodiversity, 2) it is based on explicit goals, preferably translated into quantitative, operational targets, 3) it recognizes the extent to which conservation goals have been met in existing reserves, 4) it uses simple, explicit methods for locating and designing new reserves to complement existing ones in achieving goals, 5) it applies explicit criteria for implementing conservation action on the ground, and 6) it adopts explicit objectives and mechanisms for maintaining the conditions within reserves that are required to foster the persistence of key natural features, together with an effective monitoring and adaptive management program.

Finally, regional conservation planning is precautionary. Although reserve selection algorithms, based on mathematical models that emphasize efficiency, attempt to capture maximal biodiversity in minimal area, the minimal area is properly interpreted as the area sufficient and essential to meet the stated conservation goals and objectives. “Sufficient” implies that the action can be fully expected to attain the stated goals or objective is met; “essential” implies that, without the action, the goal or objective will not be attained. Superfluous actions, such as protecting more land than necessary to assure viability of species and ecosystems, are avoided. In practice, however, the thresholds of sufficiency and necessity are always ill-defined. Estimates of what is sufficient or essential are subjective and highly uncertain, informed as much by individual experience and intuition as by hard data and rigorous analysis. The precautionary principle, which is becoming well accepted in many fields (Peterman 1990, Shrader-Frechette and McCoy 1993, Taylor and Gerrodette 1993, Noss et al. 1997), suggests that, in cases of uncertainty, it is better to risk protecting too much than too little. This precaution can be implemented in conservation planning by setting ambitious goals, while using the best available science to reduce uncertainty over time. Moreover, conservation measures can be implemented sequentially, starting with the sites of highest irreplaceability and vulnerability, then progressing to those where conservation values are lower or less certain.

Study Background and Objectives

In 1991 Reed Noss was asked by TNC (national and western regional offices) to determine conservation priorities for the GYE. This study, assisted by George Wuerthner, used information on imperiled species distributions from natural heritage programs and a variety of other maps, databases, and information to identify small and large sites throughout the region that were exceptional in their biological and ecological values. Altogether, some 11 megasites (sites larger than 200,000 acres) and 36 microsites (sites smaller than 150,000 acres) were identified that contained concentrations of imperiled species, high-quality examples of plant communities, extensive physical environmental gradients, and/or important wildlife habitats, including summer and winter range and movement corridors for large mammals. Although the state offices of TNC in Idaho, Montana, and Wyoming varied in their use of this report for conservation planning, the national office used it as part of the basis for TNC's ecoregional conservation strategy (K. Redford, personal communication).

The 1991 study was preliminary, in that it did not employ rigorous analyses of portfolio alternatives or the contribution of each site to quantitative conservation goals. The budget was inadequate to include use of geographic information systems (GIS), remote sensing, or quantitative modeling. Much has changed since 1991. The rapid growth of the human population and associated developments in the GYE, coupled with continued logging, livestock grazing, mining, and other commodity production, have lent a greater urgency to conservation decisions. Many observers believe that we have entered a narrow window of opportunity for conservation actions, a window that will be closed in 5 to 15 years. Furthermore, since 1991 a tremendous amount of new data on the biological and physical properties of the GYE and the broader region that constitutes the UWRM has become available. Most of these data are in digital format, greatly facilitating a spatially-explicit conservation assessment using GIS. New computer algorithms for assembling conservation portfolios, such as the SITES program (Andelman et al. 1999) developed for TNC, allow for more rigorous site-selection decisions. The time is ripe for more comprehensive conservation planning in the GYE, using cutting-edge analytic techniques.

The juxtaposition of high biodiversity (especially at the ecosystem level) and high levels of human impact in the UWRM create an urgent need for conservation action. Because financial resources for habitat acquisition and other conservation measures are always limited, it is imperative that conservationists target for strict protection the ecosystems and sites of highest biological priority, while providing a means to maintain ecological integrity across the broader landscape. Essentially, high-priority sites are those that have the most to lose if not protected—they are irreplaceable (Margules and Pressey 2000). Across much of the UWRM and the West in general, however, measures other than the traditional "fee simple" acquisition are the primary tools of the conservation community. As noted by Freilich et al. (2001) in TNC's Wyoming Basins Ecoregional Plan, "in Wyoming and other western states...we work with willing partners (e.g., ranchers, agency personnel and other landowners) interested in community-based conservation. Using the tools of conservation easements, agency designations, and Coordinated Resource Management plans (CRMs), we encourage conservation and compatible human activities." Nevertheless, on private lands of very high biodiversity value or at immediate risk of degradation by development, acquisition by a public or private conservation authority is often the most appropriate action. The use of any of these conservation tools requires reliable information obtained from rigorous and systematic analysis.

The theories, concepts, principles, methods, and techniques of conservation biology provide a basis for identifying key sites to be protected as core areas, connecting sites into a functional network (portfolio) that will maintain viable populations of all species and allow natural processes to operate, and identifying restoration and stewardship actions across a region needed for full ecological recovery. This process has become known as science-based conservation planning. It is not science for the sake of science—it is science in the service of conservation.

The methodology for the current assessment is a refinement of previous assessments and reserve selection and design projects applied over the last 15 years by our group (e.g., Noss 1987a, 1993, Noss et al. 1999) and many others (e.g., Bedward et al. 1992, Pressey et al. 1993, Margules and Pressey 2000, Groves et al. 2000, Poiani et al. 2000, Pressey and Cowling 2001). Our "three-track method" was first applied to the Klamath-Siskiyou ecoregion in northwestern California and adjacent Oregon (Noss et al. 1999). Several years of research and development went into this methodology, and it continues to evolve as we develop new techniques of analysis and display of data, but its basic components are simple. The method seeks to serve several basic and well-accepted goals of biological conservation (Noss and Cooperrider 1994:

- Representing all kinds of ecosystems, across their natural range of variation, in protected areas;
- Maintaining viable populations of all native species in natural patterns of abundance and distribution;
- Sustaining ecological and evolutionary processes within their natural ranges of variability; and
- Building a conservation network that is adaptable to environmental change.

In order to serve these goals, our methodology integrates three basic planning approaches that conservation biologists have pursued over the last several decades (albeit these approaches have usually been pursued separately rather than jointly):

- Protection of special elements—identifying, mapping, and protecting rare species occurrences (and particularly "hotspots" where occurrences are concentrated), watersheds with high biological values, imperiled natural communities, and other sites of high biodiversity value;

- Representation of habitats—inclusion of a full spectrum of habitat types (e.g., vegetation, abiotic habitats, aquatic habitats) in protected areas or other areas managed for natural values;

- Conservation of focal species—identifying and protecting key habitats of wide-ranging species and others of high ecological importance or sensitivity to disturbance by humans.

Together, these three tracks constitute a comprehensive approach to biological conservation. Integrating the results of site selection algorithms, population models, and other quantitative approaches with qualitative data and the experience and intuition of biologists and managers, is a defensible strategy for the protection of biodiversity (Noss et al. 1997, Pressey and Cowling 2001). This strategy forms the basis for this assessment. We emphasize, however, that this report is not the "final say" on what sites need to be protected in the UWRM or how they might be protected. As acknowledged in TNC's handbook on ecoregional planning, *Designing a Geography of Hope* (Groves et al. 2000: 3-3), "the result of most ecoregional planning efforts is an identification of generalized **areas of biodiversity significance**, not conservation sites where the targets, threats, and strategies/plans to abate threats have been analyzed with considerably more rigor than in ecoregional planning" (emphasis in original). In other words, there is more work to be done!

OVERVIEW OF THE ECOREGION

The Ecosystem Defined

The Utah-Wyoming Rocky Mountains Ecoregion (Fig. 1) encompasses most of what is known to biogeographers as the Middle Rockies. It includes the mountains just north of Yellowstone National Park in south-central Montana, the Bighorn Mountains in northeast Wyoming, the Uinta Mountains of northeast Utah and Northwest Colorado, Utah's Wasatch Range, and the mountains and valleys of the southeastern corner of Idaho, generally east of Interstate 15.

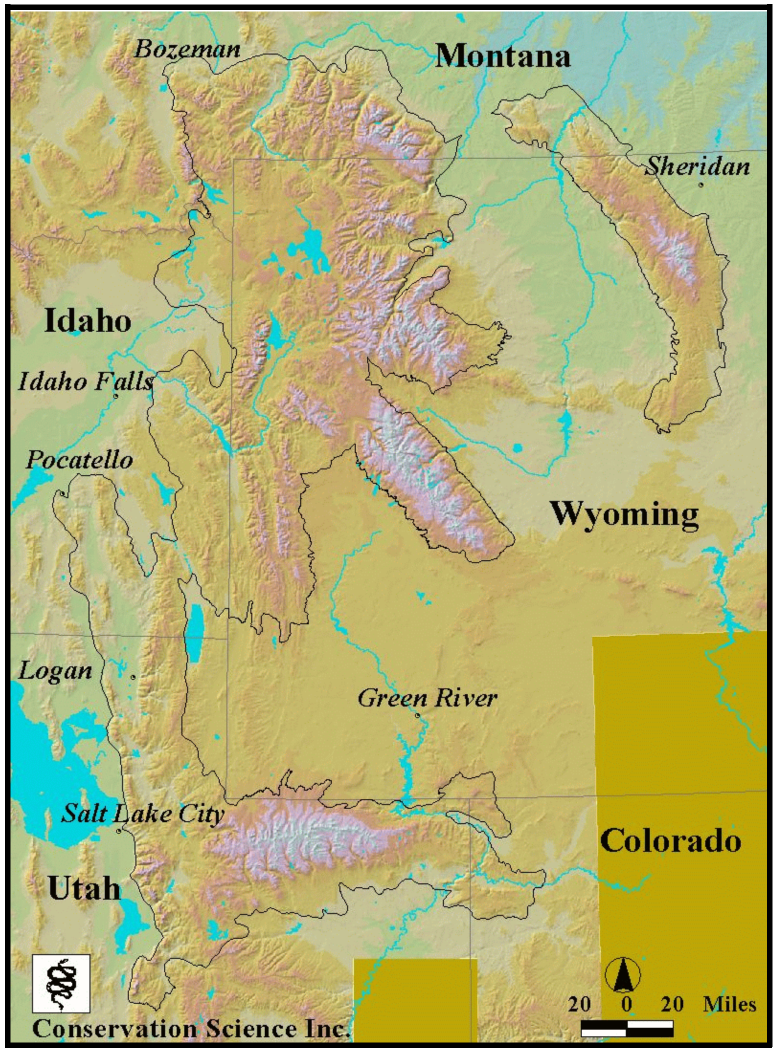


Figure 1. Utah-Wyoming Rocky Mountains Ecoregion (UWRM)

Embedded in this vast area is the Greater Yellowstone Ecosystem (GYE), with Yellowstone National Park as its focal point. The GYE is considered one of the last intact temperate ecosystems on Earth, and the farthest south in North America. Yellowstone is an extraordinary place containing the greatest concentration of geysers, hot springs, and other thermal features in the world. Not surprisingly it is a World Heritage Site.

The wildlife of the GYE is among the most vigorous and intact in North America. Yellowstone Park is the only large area in the coterminous United States that has never been farmed, ranched, or logged. Hence, the area is home to all the native species that existed at the time when the first Europeans explored the region except for the passenger pigeon. The GYE contains a minimum of 337 species of mammals, birds, and fish, and more than 12,000 species of insects. It is home to one of the last remaining grizzly bear populations in the lower 48 states and the last continuously wild buffalo herd in the country. It has the greatest concentration of elk in the world. And its cold water fisheries are world famous (Wuerthner 1992).

Perhaps more importantly, such ecosystem-scale ecological processes as wildfire and predation by large predators such as the wolf still function over much of the landscape. In partial recognition of its exceptional biological, geological, and historical value, much of the Greater Yellowstone Ecosystem is protected from unbridled development with key areas like Yellowstone National Park and Grand Teton National Park as core components of this ecosystem.

The outlying areas of the UWRM include Wyoming's Bighorn Mountains as well as Utah's Uinta Mountains and Wasatch Range. All have attributes similar to the core GYE, albeit on a smaller scale. The 150 mile long Bighorn Mountain Range is an isolated outlier of the Rockies, and indeed, many of its animals, including snowshoe hare, marten, and others may be genetically distinct races. The Uinta Mountains contain Utah's largest protected wilderness, the 460,000-acre High Uinta Wilderness. With more than 2,000 lakes and wetlands, the Uintas are well-watered and serve as headwaters for the majority of Utah's major watersheds. Dinosaur National Monument, also on the fringe of the Uintas, protects some of the West's most dramatic canyon country. The spectacular Wasatch Range, rising steeply along the Wasatch Fault above the populated Wasatch Front communities where 90% of Utah's population resides, is equally unique. The range frames the eastern edge of the Great Basin, is comparatively well watered for Utah, and is home to many species including some of the richest mollusk diversity in the West.

Given their relative isolation, these outlying mountain areas have suffered greater species loss than the core GYE. Populations of some species, particularly predators, were locally extirpated. Nevertheless, many of these areas, including the Uinta Mountains and the Bighorn Mountains may be large enough to support populations of such predators as lynx, wolverine, wolf, and grizzly bear, especially if functionally connected to the GYE.

In recent years many biologists have recognized that most protected landscapes like national parks are in and of themselves, too small to maintain fully functioning ecological processes and representative populations of all native species (Newmark 1985, Noss and Cooperrider 1994). Thus, the idea of expanded, landscape-scale protection strategies has evolved and has been frequently discussed for the GYE. This concept applies equally to the UWRM as a whole. Numerous threats exist to the long-term biological integrity of this region. Human activities include logging, mining, oil and gas development, livestock production, industrial tourism, and a burgeoning population growth with attendant issues of sprawl and development. Not all of these threats affect every acre of the ecoregion, but their cumulative influences are leading to significant biological impoverishment and functional disruption. Fortunately for the biological future of this region, sustaining the ecoregion's biological capital is becoming increasingly recognized as key to sustaining its economic health and human communities as well (Power, 1996, Rasker and Alexander 1997).

Climate

As a high mountainous region in the interior West more than 800 miles from the moderating effects of the Pacific Ocean, the climate of the ecoregion is generally characterized as cold continental. Winters are long and summers short. Snow cover at 7,000 feet in Yellowstone Park typically lies upon the ground for an average of 213 days and lasts another 29 days for every 1000 feet of elevation gain (Despain 1990).

Climatic conditions interacting with topographical features affect many aspects of the ecoregion's biological heritage. The greater acreage and abundance of aspen in the southern part of the ecosystem is a consequence of greater summer rainfall, while the abundance of big game that winter in the Gardiner, Montana area is a consequence of low precipitation created by rain shadow effects. In general, the western part of the ecosystem in Idaho and adjacent parts of Montana and Wyoming receives the greatest annual precipitation. This is readily apparent to anyone who travels extensively around the region, with places like the south slope of the Centennial Range, the west slope of the Tetons, and other mountains in the western and southwestern parts of the ecosystem appearing extremely lush. For example, the southeast corner of Yellowstone National Park often receives more than 80 inches of annual precipitation (Despain 1990).

On the other hand, the eastern and northern edge of the ecosystem downslope from high mountains like the Wind River Range, Absaroka Range, Gravelly Range, and Beartooth Mountains are easily the driest parts of the region. For example, the "Bridger Desert" just east of the Beartooth Front on the Montana-Wyoming border is one of the most arid parts of Montana receiving less than 6 inches of precipitation annually in some areas (Merrill and Jacobson 1997). Belfry on the edge of this desert gets only 6.8 inches annually. For comparison, Tucson, Arizona in the Sonoran Desert receives 12 inches of annual precipitation—nearly twice as much as Belfry. The Big Horn Basin east of Cody is also extremely arid, and the second driest location in Wyoming (Knight 1994).

A similar pattern is seen in Wyoming. Afton to the west of the Salt River Range and Wyoming Range gets 17.98 inches of precipitation annually while La Barge to the east of the Wyoming Range in the Green River Valley receives only 8.31 inches. Contrast these figures with areas further to the West. Moose in Jackson Hole receives 21.38 inches of precipitation, even though it lies in the shadow of the Tetons, while Dubois at nearly the same elevation but east of the mountains in the Upper Wind River Valley gets only 9.17 inches of annual precipitation.

These statistics in part reveal a curious dichotomy in the ecoregion's climate regime. One part of the ecosystem is dominated by a summer/dry—winter/wet characteristic of the Pacific Northwest, while the other is a winter/dry—summer/wet typical of the Southwest and southern Plains. The region sits at the intersection of these major climatic regimes (Whitlock and Bartlein 1993). This further exaggerated by the rain shadow effect created by the regional mountain ranges.

The western portion of the ecoregion, influenced more by Pacific coastal storms, receives most of its precipitation as late winter snowpack—particularly spring snowfall and early summer rains. Livingston, Montana in the northern part of the ecosystem receives its greatest precipitation in May and June, with rainfall tapering off dramatically in July and August. Island Park, Idaho expresses this more dramatically with two peak precipitation periods, one occurring in January and February and another in May and June. This pattern has a significant effect upon plant growth. Heavier winter snow means greater snowpack depth and a longer period of melt in the summer. The high May and June peaks, when combined with melting snowpack can result in significant flood events.

Areas further to the south and east of Yellowstone National Park receive proportionally more precipitation in summer, particularly by summer monsoon thunderstorms (Despain 1987, Whitlock and Bartlein 1993). In particular the Bighorns, Uintas, Wind River Range, Wyoming Range, and adjacent parts of southeast Idaho are characterized by frequent intrusions of warm moist monsoon air masses from the Gulf of Mexico. When these air masses are lifted up over the high peaks of the ecosystem, thundershowers become an almost daily occurrence in July and August.

One consequence of this pattern may be the greater abundance of aspen and willows in the southern and southeast portions of the ecoregion and the near absence of large concentrations of these species in the northern parts of the ecoregion. Aspen and willow depend upon abundant water during the summer growing season. In the northern part of the ecoregion, aspen are limited primarily to sites near surface water sources or where snow melt collects, while in areas dominated by monsoon summer rains, aspen is more widespread over the landscape. The abundance of aspen as a percentage of forest cover grows as one moves south and east with the Bighorns, the ranges of the southern Bridger Teton National Forest, Uintas, and Wasatch Range having far more area covered with aspen than areas further north in Montana's Beartooth, Absaroka, Gallatin, and other ranges.

These differences in vegetation, in turn, result in significant differences in wildlife numbers and population structure. Moose and beaver, which browse extensively on willows and aspen, are more abundant in the southern part of the region, and only found in low numbers over most of the northern portions of the ecosystem.

The regional climate has oscillated considerably in the past (Millspaugh et al. 2000). For instance, between 1600 and 1850 the region experienced the effects of the Little Ice Age that led to greater snow accumulations, expansion of glaciers, and generally cooler summers. Global change induced by the burning of fossil fuels is leading to warmer temperatures and greater intensity of storms. It has the potential to shift climate zones hundreds of miles to the north and upward a thousand feet or more on mountains. This could cause the local extinction of many alpine and subalpine species as habitat shrinks or is eliminated (Graumlich 1991). Whitebark pine, already stressed by white pine blister rust, may disappear completely from the ecoregion. Fires may increase in frequency and intensity (Romme and Turner 1992).

Major Plant Communities

The UWRM is dominated by extremes in climate that include long periods of cold, heavy snow, and often-arid summer conditions. Depending upon elevation, these environmental constraints limit the number of plants that can adapt to these conditions. The lowest elevations tend to be treeless except along riparian zones and dominated by grass-shrub communities. A broad belt of forest is found throughout the middle elevations, with alpine tundra found at the highest parts of the mountain uplifts (Despain 1990, Knight 1994).

At the lowest and driest locations one can find pockets of saltbush, greasewood, and winterfat along with bluebunch wheatgrass, prairie junegrass, and occasional pockets of Great Basin wild rye. For example, these plants occur in the rainshadow of the Beartooth Mountains in the Bridger Desert region, near Gardiner in the Upper Yellowstone River Valley, and in the Upper Wind River Valley and Big Horn Basin. At slightly higher elevations various species of sagebrush begin to dominate, including Great Basin big sagebrush, Wyoming big sagebrush, and mountain big sagebrush. Grasses continue to be dominated by bluebunch wheatgrass, Idaho fescue, needle-and-thread grass, and Kentucky bluegrass along riparian areas.

Riparian species found along waterways include willow species, red osier dogwood, wild rose, and chokecherry. Trees include one of three species of cottonwood, plus blue spruce in some parts of the southern end of the ecosystem, north to the upper Gros Ventre, Hoback, and upper Wind rivers. Many of these riparian communities have been negatively impacted by livestock production and dams (Merigliano 1996), making them some of the most endangered communities in the ecosystem.

Depending on the location, either ponderosa pine, Douglas-fir, or Rocky Mountain juniper is the first tree species that typically delineates the lower tree line. Ponderosa pine is relatively scarce in the region and tends to be found where summer precipitation is highest (Knight 1994). Ponderosa pine is found in the northeast section of the ecosystem along the Yellowstone River from Big Timber eastward, along the eastern slope of the Bighorn Mountains, and along the eastern and southern slopes of the Uintas. Juniper is found in some parts of southeast Idaho, east of the Beartooth Mountains along the Clarks Fork drainage, along the fringes of the Bighorn Basin, and on the eastern and southern portions of the Uinta Mountains. Throughout most of the ecosystem, Douglas-fir is the dominant low elevation tree species and is even common in those areas where juniper or ponderosa pine also occurs (Knight 1994). Limber pine occurs throughout the ecosystem on dry, windy sites. It is found both at the lower timberline and at high elevations on mountains.

As one moves higher in elevation, Douglas-fir is intermixed with aspen. Aspen is most abundant in the southern end of the ecosystem and relatively uncommon in the northern reaches of the area, most likely as a consequence of greater summer precipitation that characterizes the southern mountains of the ecosystem (see discussion above). It is particularly abundant in the Wasatch and

Uinta Mountains. Bigtooth maple is found from the Snake River Canyon in Wyoming southwards through Southeast Idaho and into the Wasatch Range of Utah. Gambel's oak occurs in the southern part of the ecoregion from the central Wasatch southward.

Engelmann spruce, subalpine fir, and lodgepole pine dominate mid-elevation forests. White fir replaces subalpine fir from the central Wasatch southward. The spruce-fir forest tends to be the climax association and would dominate more of the area were it not for recurring stand-replacement fires that favor lodgepole pine. At the highest elevations whitebark pine is a dominant tree species. This pine is most common in the eastern parts of the ecosystem, particularly on the Shoshone National Forest. Whitebark pine throughout the ecoregion suffers from white pine blister rust.

Beyond timberline, extensive tracts of alpine tundra occur, generally at elevations above 10,000 feet. Indeed, over half of the Beartooth Mountains consist of tundra, the most extensive continuous occurrence of alpine tundra in the lower 48 states. Extensive tracts of alpine tundra are common in the Wind River Range, Absaroka Mountains, Uinta Mountains, and Bighorn Mountains.

Human Populations and Communities

By far and away the largest population center in the ecoregion is the Wasatch Front. More than a million people live in the cities that stretch for more than a hundred miles from Provo north to Brigham City and Logan. The Wasatch Front is also one of the fastest growing regions in the entire West, and its population is expected to double within 25 years.

Beyond the Wasatch Front, the rest of the ecoregion is sparsely populated. Other larger communities include Pocatello, Idaho Falls, Billings, and Bozeman. Most of these cities lie on the fringes of the ecoregion. Nevertheless, population is growing rapidly in some parts of the ecoregion. For instance, the 20 countries making up GYE grew at a regional rate of 14 percent between 1990 and 1999 (Greater Yellowstone Report 2000). Four of ten fastest growing counties in Montana are located in the GYE (Merrill and Jacobson 1997). Teton County, Idaho, located on the western slope of the Teton Range experienced the greatest growth in the region—a phenomenal 66.0%! Other fast growing counties include Gallatin County in Montana with a growth rate of 26.5% and Teton County, Wyoming, which grew by 30.1%. Only Hot Springs County in Wyoming actually lost population. A study (Harting and Glick 1994) in 1991 found that more than a million acres in the GYE had already been subdivided.

PLANNING METHODOLOGY

The Three-Track Approach to Setting Conservation Targets and Goals

Most existing conservation areas in the UWRM, as elsewhere, were selected opportunistically and for such non-biological reasons as scenery, recreational potential, and lack of conflict with resource extraction objectives (Pressey et al. 1993, Noss and Cooperrider 1994, Scott 1999, Scott et al. 2001). Recently, principles and techniques from the science of conservation biology have been applied to reserve selection and design and other conservation challenges (Scott et al. 1993, Csuti et al. 1997, Noss et al. 1997, Margules and Pressey 2000). Since scientists became involved, as scientists, in conservation planning, a multitude of approaches have been applied, reflecting the skills and interests of individual scientists and the technical tools available. Most of these approaches, however, are variants of three basic tracks which, in turn, reflect different goals: (1) protection of special elements, such as rare species hotspots, old-growth forests, and critical watersheds for aquatic biota, (2) representation of all habitats, vegetation types, or species within certain indicator taxa within a network of reserves, and (3) meeting the needs of particular focal species, especially those that are area-dependent or sensitive to human activities (Noss 1996, Vance-Borland et al. 1995/96, Noss et al. 1999).

These three approaches to conservation planning have been applied by scientists and conservationists for decades, but they have been applied separately rather than in an integrated fashion. Importantly, each approach—or even different ways of conducting a given approach—arrives at a unique set of conservation priorities, which are often difficult to reconcile with the priorities established by other methods. Someone interested in rare plants, for instance, will arrive at different conservation priorities than someone interested in songbirds; both will differ in their conclusions from someone interested in representing examples of all plant communities in reserves or maintaining a viable population of grizzly bears. Few previous plans have combined all three tracks, yet such a combination is necessary to make fully informed decisions about land allocation and management. One of the first attempts to integrate the three tracks into a single comprehensive assessment was a conservation plan we produced for the Klamath-Siskiyou ecoregion of northwestern California and adjacent Oregon (Noss et al. 1999). We have expanded on that approach in the present study.

All conservation assessments ultimately require decisions about which components of the natural biota will be analyzed and assessed. Although conservationists legitimately seek to conserve all of biodiversity, limited knowledge about the diversity and distribution of many taxa precludes exhaustive mapping of distributions or comprehensive determination of protection priorities. We have no choice but to focus on surrogates, but the choice of surrogates must be made carefully (Margules and Pressey 2000). Surrogates for biodiversity might include sub-sets of species that are well known taxonomically, well-inventoried species groups, rare species, species assemblages or communities, vegetation types, or physical (abiotic) habitats.

The extent to which the distributions of surrogate taxa coincide with the distributions of other taxa is often uncertain. Centers of species richness for different taxonomic groups often do not overlap, or overlap only slightly (Prendergast et al. 1993), such that identifying hot spots on the basis of one or few taxa may be misleading. Moreover, identified hot spots of species richness or endemism are only as reliable as the underlying data. In most cases, biological surveys are spotty. Areas that show up as “cold spots” could either be areas where species richness or endemism is truly low or they could simply be areas that were never surveyed. Hence, relying on a single approach to conservation assessment is foolhardy. We hypothesize that the three-track approach compensates for misleading information that might be obtained from any single approach pursued in isolation.

Beginning in the 1970s, with pioneering work by its Vice President for Science, Robert Jenkins, TNC developed a "fine filter/coarse filter" approach to the inventory and protection of species and natural communities (Noss 1987b). The fine filter focuses on species and populations and is an example of the special elements track. Individual occurrences of imperiled species (which may or may not correspond to populations) are located, mapped, and targeted for protection. This approach, as traditionally pursued, works well for plants and small-bodied animals, but not so well for large-bodied, wide-ranging animals. Again, it is dependent on comprehensive, or at least well distributed, biological surveys to be most useful.

The coarse filter, on the other hand, seeks to protect high-quality examples of all natural communities or ecosystems in a region. If applied to small, localized occurrences of imperiled community types, as it often has been in practice, the coarse filter is really not much different from the fine filter. If applied on a landscape scale, however, with the notion of representing all ecosystems in a region across their natural range of variation, the coarse filter is complementary to rare-species conservation (Noss 1987b).

The coarse filter is an example of the representation track, the history of which extends back to the late 19th century in Australia and the early 20th century in North America (Noss and Cooperrider 1994, Scott 1999). In America, this effort was led by Victor Shelford, who was instrumental in the founding of the Ecological Society of America in 1916 and TNC in 1950 (Croker 1991). In1917, at Shelford's urging, the National Research Council asked the Ecological Society to prepare a "listing of all preserved and preservable areas in North America in which natural conditions persist" and "to urge the reservation of such areas as demanded immediate attention." Shelford established a "preservation committee" to accomplish this task, the first major product of which was *A Naturalist's Guide to the Americas* (Shelford 1926). By 1931 the work was being carried out by two sister committees: a fact-finding body, the Committee for the Study of Plant and Animal Communities, and an action body, the Committee on the Preservation of Natural Conditions. Their goal was "a nature sanctuary with its original wild animals for each biotic formation" (Croker 1991). Although Shelford's committees had some influence on the establishment of particular national parks and monuments, such as Glacier Bay in Alaska, they left the task of representing all North American ecosystems in protected areas to another generation or two.

One of the strongest arguments for the representation strategy is that it is likely to capture species, genes, and other elements of biodiversity that are poorly known or surveyed. Bacteria, fungi, bryophytes, and many invertebrate groups, for instance, would rarely be considered in the special elements track, simply because data on their distributions are not available. Given that species distributions are determined largely by environmental factors, and that vegetation and abiotic habitats represent gradients of these factors across the landscape, protecting examples of all types of vegetation or physical habitats ought to capture the vast majority of species without having to consider those taxa individually. TNC has estimated that 85-90% of all species can be protected by the coarse filter (Noss 1987b). This assumption has never been tested empirically, as doing so would require a complete inventory of all organisms, including cryptic taxa such as bacteria, over a broad area. Nevertheless, we consider it a reasonable hypothesis. Species that fall through the pores of the coarse filter—such as narrow endemics—can be protected through the fine filter of species-level conservation (i.e., special elements).

In some cases conservation planning for individual species provides more of a coarse-filter than fine-filter function. For example, conservation of mammalian carnivores and other large-bodied species generally requires protection of suitable habitat conditions over large areas, hence providing protection to many other species. These animals are often considered umbrella species because they provide an umbrella of protection to many other species (Noss 1991, Simberloff 1998, Miller et al. 1998/99). Moreover, because these species are sensitive to the size and configuration of habitat patches across a landscape, they are indicators of ecological conditions at broad scales and, therefore, are helpful in the process of regional conservation planning.

Consideration of such large-bodied and sensitive species constitutes the third track in our approach—focal species. Although we acknowledge that a comprehensive set of focal species would encompass species sensitive to a broad range of environmental factors (e.g., resource abundance and disturbance frequency and intensity) across a range of terrestrial and aquatic habitats (Lambeck 1997), we selected four carnivores and an ungulate as the focal species for this assessment: grizzly bear (*Ursus arctos*), gray wolf (*Canis lupus*), wolverine (*Gulo gulo*), lynx (*Felis lynx*), and elk (*Cervus elaphus*). Our research indicates that these species, collectively, respond to a broad range of landscape features and provide ecological indicator and umbrella values. The GYE (i.e., the northwestern portion of the UWRM) is especially significant in terms of focal species, as it possesses what is probably the densest elk population in the world and is the most southerly area in North America with potentially viable populations of grizzly bear, wolf, and wolverine (Clark et al. 1999). Moreover, the potential exists for expansion of carnivore populations from the GYE to other portions of the UWRM. Hence, our assessment places greater emphasis on focal species than most previous multi-criteria conservation plans.

Several possible approaches may be used to integrate focal species analysis into the broader conservation planning process. A useful conceptual framework divides these approaches into three types: prospective, retrospective, and surrogate analyses (Mehlman 1997). In *prospective* analysis, the most common type, critical habitat areas for all species of concern are identified and some of these areas are incorporated into a portfolio using principles of efficiency and complementarity. A *retrospective* approach first designs a portfolio using fine-filter and coarse-filter techniques that aim to represent all vegetation or other habitat types, as well as imperiled species and communities, then evaluates whether the portfolio adequately captures the critical habitats of focal species, and if not, which areas should be added. A *surrogate* approach confronts the fact that data are lacking for many species of concern, and therefore a well-selected subset of the potential focal species may be used to identify the conservation needs of the broader group of species. As mentioned earlier, virtually all conservation assessments and plans require use of surrogates (Margules and Pressey 2000).

Our approach incorporates elements of prospective, retrospective, and surrogate analysis. We assume that the level of detail needed for analysis of the conservation needs of species will vary depending on where each species falls in a hierarchy of categories, each of which receives progressively more detailed study. The largest group of species will have the habitat needed for their viability captured by a coarse-filter approach which seeks to represent all vegetation and geoclimatic types (see above). Most non-endemic plants, invertebrates, and small vertebrates fall into this category (i.e., these are largely the local-scale species recognized by TNC; Groves et al. 2000, Poiani et al. 2000). Other species may need additional habitat, but can be expected to have their needs captured by the habitat reserved for other species within their community or guild. This is the umbrella species assumption. For example, the area requirements of a small mammalian carnivore or a small woodpecker generally would be met by considering the requirements of a larger carnivore or woodpecker species, respectively, that use the same habitat types.

Still other species require individual attention. Narrow endemics and other rare species with small area requirements (e.g., local-scale species) can be protected through the fine filter of the special elements track. Species that depend upon localized resources such as distinct wintering areas would also fall into this group. We suggest that the needs of other species can best be considered through habitat modeling approaches. For species unlikely to show strong area or connectivity limitations, given the relationship between their life-history characteristics (territory size, population density, dispersal ability) and current landscape condition, the optimal approach is often to select the highest quality habitat as identified by a static empirical or conceptual model (i.e., a habitat suitability model; see Carroll et al. 1999, 2000, 2001).

Nevertheless, a few species can be expected to show strong spatiotemporal dynamics that are not adequately addressed by static models. To create a coherent regional-scale conservation strategy for these species, dynamic modeling that integrates demography and habitat configuration is useful. These species are usually those that have relatively small populations, require a large area of habitat, or do not disperse easily across common habitat types forming the landscape matrix (e.g., developed or non-forested habitat). All of our carnivore focal species fit this description to one degree or another.

Our three-track approach is generally consistent with the approach TNC has taken to ecoregional planning over the last couple years (Groves et al. 2000), except that we place more emphasis on modeling habitat suitability and population viability for focal species, and on quantitative assessment in general, than have previous ecoregional plans. Our approach to integrating static and dynamic models for focal species appears to be unique in ecoregional planning, as is our representation assessment (described below), which integrates vegetation and abiotic (geoclimatic) habitat data. Moreover, we combine these quantitative approaches with the expert knowledge of the ecosystem provided by our team members (especially George Wuerthner), the many experts consulted during the course of this project, and the participants in the workshops that reviewed the draft results.

Planning Units

The building blocks of a conservation plan are the sites that are compared to one another in the conservation assessment. We used 6th-level watersheds as planning units because they are ecologically relevant and are of a convenient scale for regional planning. Among other advantages, using watersheds as planning units allows site selection algorithms to represent aquatic systems as intact and connected units. Nevertheless, 6th-level watersheds had not been delineated for most of the study area. Therefore, we created pseudo (modeled)-6th-level watersheds using the BASINS function in ArcInfo GRID geographic information system (GIS) software, based on a 90 m digital elevation model. To better conform the resulting polygons to recognized watersheds, we merged them with USGS 5th-level watersheds. We eliminated polygons smaller than 2,000 ha (leaving the official 5th-level watershed lines intact) and further divided several large polygons to avoid potential species-area effects, which could bias the site selection algorithm. To distinguish existing protected areas from other lands, we merged the watershed polygons with USGS Gap Analysis Program (GAP) management status 1 (strictly protected) and 2 (moderately protected) polygons. This procedure resulted 2379 planning units, ranging in size from 1 ha (2.47 acres) to 39,473 ha (97,498 acres) and averaging 4,604 ha (11,372 acres). (The smaller units were watersheds partly within existing protected areas. Only the portions of the watersheds that fell outside protected areas were considered planning units in this analysis, as we assumed that protected areas are, in fact, already protected.) GAP level 1 and 2 protected areas constitute 3.3 million hectares (8,151,000 acres), or 30%, of the 10.9 million hectare (26,933,900 acre) UWRM study area.

The SITES Selection Algorithm

Early conservation assessments and reserve designs depended on manual mapping to delineate sites and on simple scoring procedures to compare and prioritize sites. The large number of conservation targets and the large size and diverse types of data sets describing the targets in this study required the use of a more systematic and efficient site selection procedure. We used the site selection software SITES (v1.0), developed at the University of California, Santa Barbara under contract to TNC, as an aid to portfolio assembly. SITES operates within ArcView GIS as "an analytical toolbox for designing ecoregional conservation portfolios" (Andelman et al. 1999). SITES has been or is being used as an aid for designing and analyzing alternative portfolios in a number of TNC ecoregional plans, including the Northern Gulf of Mexico (Beck et al. 2000), Cook Inlet, Klamath Mountains, Sierra Nevada, Middle Rocky Mountains-Blue Mountains, and Southern Rocky Mountains ecoregions.

SITES utilizes an algorithm called "simulated annealing with iterative improvement" as a heuristic method for efficiently selecting regionally representative sets of areas for biodiversity conservation (Pressey et al. 1996, Csuti et al. 1997, Possingham et al. 1999). It is not guaranteed to find an optimal solution, which is prohibitive in computer time for large, complex data sets such as ours. Rather, the algorithm attempts to minimize portfolio "cost" while maximizing attainment of conservation goals in a compact set of sites. This set of objectives constitutes the "Objective Cost function:"

Cost = Area + Species Penalty + Boundary Length

where Cost is the objective (to be minimized), Area is the number of hectares in all planning units selected for the portfolio, Species Penalty is a cost imposed for failing to meet target goals, and Boundary Length is a cost determined by the total boundary length of the portfolio.

SITES attempts to minimize total portfolio cost by selecting the fewest planning units and smallest overall area needed to meet as many target goals as possible, and by selecting planning units that are clustered together rather than dispersed (thus reducing boundary length). SITES accomplishes this task by changing the planning units selected and re-evaluating the Cost function through multiple iterations. We had SITES perform 1,000,000 iterative attempts to find the minimum cost solution per simulated annealing run and perform 10 such runs for each alternative conservation scenario we explored. Alternative scenarios were evaluated by varying the inputs to the Cost function. For example, the Species Penalty cost was increased for some targets (such as heritage elements with high EO-ranks) and decreased for others (such as modeled habitat types); and the Boundary Length cost factor was increased or decreased depending on the assumed importance of a spatially compact portfolio of sites. Varying the inputs to SITES in order to assess the outcome, in terms of the planning units selected, allows portfolio design to be tailored to expert opinion, while quantifying the effects of such subjective decisions.

We used numerous SITES runs to determine alternative portfolios which met stated goals for protection of the target groups: local-scale imperiled species, bird species, aquatic species, and plant communities within the special elements track; vegetative, abiotic, and aquatic habitat types within the representation track; and high-quality habitat for the several species analyzed within the focal species track. We made SITES runs with and without existing protected areas “locked in” to the portfolio, looking for differences in the location and area of selected planning units. We examined alternative scenarios emphasizing different land ownerships (public vs. private) to assess the different ways public and private lands might contribute to regional conservation. We also used output from focal species habitat suitability models and dynamic population models as input to SITES to identify key areas for long-term focal species viability (i.e., prospective analysis), and alternative SITES portfolios as input to dynamic population models to evaluate how well different portfolios might maintain focal species populations (i.e., retrospective analysis). Our ultimate objective was to find the portfolio that met stated goals for all target groups in an efficient manner, while also meeting the general criteria of reserve design (e.g., connectivity, minimal fragmentation).

Special Elements

Following general TNC guidelines (e.g. Groves et al. 2000) and considering the recommendations of staff scientists in the five state heritage programs, we compiled an extensive list of targets (species, communities, and ecological systems) categorized into 6 classes with associated goals (Appendix A).

The targets in Appendix A encompass the three tracks of special elements, representation, and focal species. Classes 1, 2, 4, and 5 constitute special elements, in that relatively discrete occurrences or habitats can be mapped and evaluated for potential inclusion in a portfolio of sites. Class 3 is focal species—coarse-scale or regional-scale species—which were addressed through habitat modeling and population viability analysis that extrapolated beyond known occurrences. Class 6 constitutes ecological systems—GAP vegetation types, physical (abiotic) habitats, and aquatic habitats, which were addressed by a representation approach.

We assembled element-occurrence (EO) data for the study area from state natural heritage programs in Montana, Idaho, Wyoming, Utah, and Colorado. After excluding occurrences of species or communities last observed prior to 1982, or ranked as non-viable or non-breeding occurrences by the heritage programs, 2961 occurrences of 563 species and communities remained (Fig. 2), 416 of them for the 109 species and communities with conservation status ranks of G1 (critically imperiled globally) or G2 (imperiled globally). We divided the occurrence data into four target groups for separate SITES analyses: local-scale species (class 1 targets in Appendix A), bird species (class 2), coarse- and regional-scale aquatic species (class 4), and plant communities (class 5). We set goals for 100% capture of the G1 and G2 occurrences in all target groups and capture of at least 10 occurrences of lower conservation status. A SITES portfolio had to meet these goals or was penalized as part of the cost function.

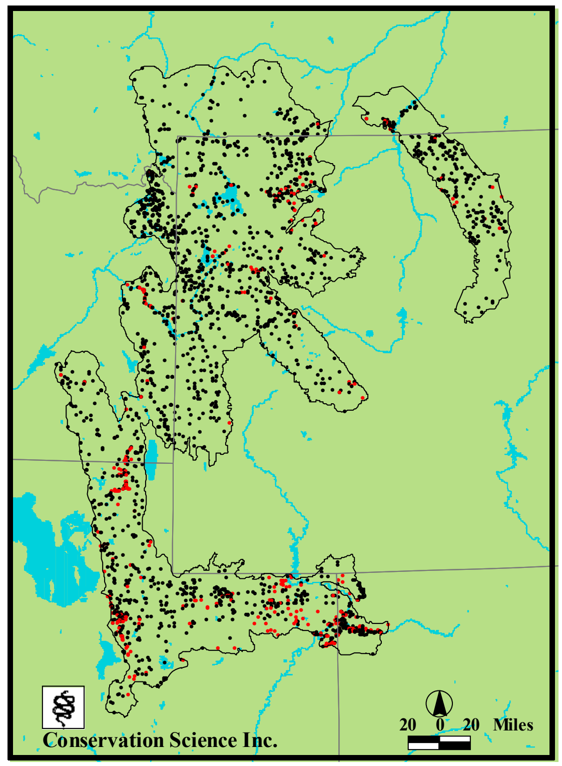


Figure 2. UWRM natural heritage data. G1 and G2 in red, others black

We made 10 repeat runs in SITES for each special elements target group, using the "sum runs" option. Each run consisted of one million iterations, the number of attempts the algorithm makes to find a solution. Output from the sum runs option includes both the best portfolio solution of the 10 ("best runs"), and how many times each planning unit was included in the10 different portfolios. Planning units containing G1 or G2 elements appeared in all 10 runs because 100% of those occurrences were targeted. Similarly, planning units in GAP level 1 and 2 protected areas appeared in all runs for scenarios with existing protected areas locked in. We used the number of times planning units were selected for SITES special elements solutions in scoring proposed megasites in terms of their irreplaceability for meeting special elements goals (see below).

Representation

TNC recommends the identification of "ecological systems" that represent the entire range of ecosystems found within an ecoregion. Ecological systems are defined by Grove et al. (2000:3-4) as:

> dynamic spatial assemblages of ecological communities that 1) occur together on the landscape; 2) are tied together by similar ecological processes (e.g., fire, hydrology), underlying environmental features (e.g., soils, geology), or environmental gradients (e.g., elevation, hydrologically-related zones; and 3) form a robust, cohesive, and distinguishable unit on the ground. Ecological systems are characterized by both biotic and abiotic (environmental) components and can be terrestrial, aquatic, marine, or a combination of these.

The terrestrial ecological systems of the UWRM have not been classified. Hence, we used a combination of vegetation types mapped by the state Gap Analysis Programs (GAP) and a new classification of physical (abiotic; geoclimatic) habitats in an effort to represent terrestrial ecological communities across environmental gradients. Each GAP vegetation type, recognized by interpretation of satellite imagery, is fairly coarse and covers a spectrum of physical habitats. By setting representation goals for both vegetation and abiotic habitats, we strove to capture much of this otherwise hidden beta diversity (Noss et al. 1999) and serve the basic objectives of TNC's ecological systems approach. Representing the full spectrum of geoclimatic habitats—ideally along intact environmental gradients—may facilitate the micro- and meso-scale shifts in distribution that species will need to make in response to climate change. For aquatic communities, we used the aquatic ecological systems classification developed by Mary Lammert, Aquatic Ecologist with TNC's Freshwater Initiative.

Vegetation

The USGS Gap Analysis Program has mapped vegetation types in the three states included in the project. We merged the vegetation maps into a single map that includes 44 vegetation types in the study area (Fig. 3). These vegetation types correspond generally to the alliance level of classification hierarchy.

We performed a gap analysis (Scott et al. 1993) to judge how well the existing system of protected

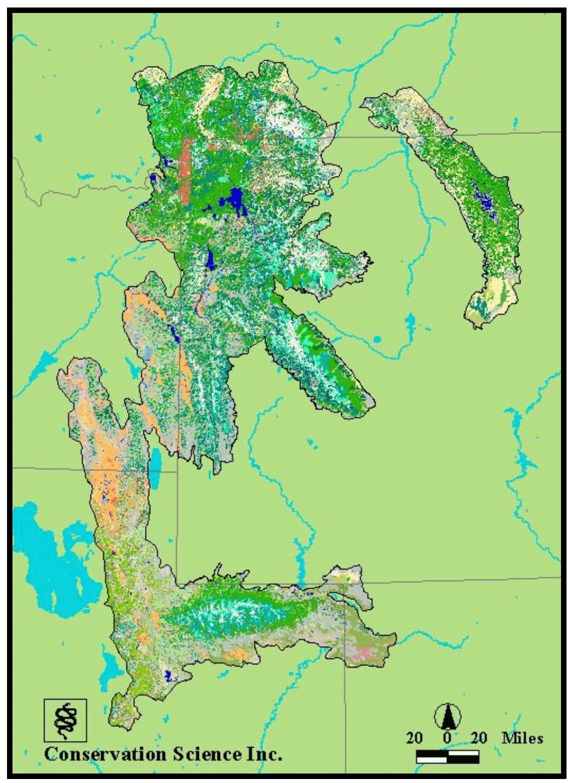


Figure 3. UWRM Gap Analysis Program vegetation types.

areas represents regional vegetation types. We used SITES to develop portfolios of planning units that would protect at least 35% of the area of each wetland vegetation type (lowland riparian, mountain riparian, water, wetland, wet meadow) and 25% of the area of each other vegetation type. We set a higher target for wetland vegetation types because of their relative rarity and high value for biodiversity in this region. As with special elements, we used the sum runs option in SITES to determine how frequently planning units were selected for portfolio solutions to represent vegetation types, then used that information to determine irreplaceability scores for megasites in the proposed portfolio.

Physical Habitats

The physical habitat classification was performed in ArcInfo GRID using PRISM climate data and STATSGO soils data. We entered PRISM mean monthly precipitation and mean monthly minimum and maximum temperatures into principal components (PRINCOMP) analyses to find the major components of climate variation in the study area: 1) mean annual precipitation; 2) spring (May and June) precipitation; 3) mean annual low temperature; 4) mean annual high temperature; and 5) the difference between winter (December, January, and February) mean low temperature and summer (June, July, and August) mean high temperature. We also used mean annual growing degree days, another PRISM variable, in the classification. Soil depth, water-holding capacity, and organic carbon content were all derived from the STATSGO soils database. The nine climate and soils variables were used in a cluster analysis (ISOCLUSTER and MLCLASSIFY) which identified 43 physical habitat types in the study area (Fig. 4; Appendix A).

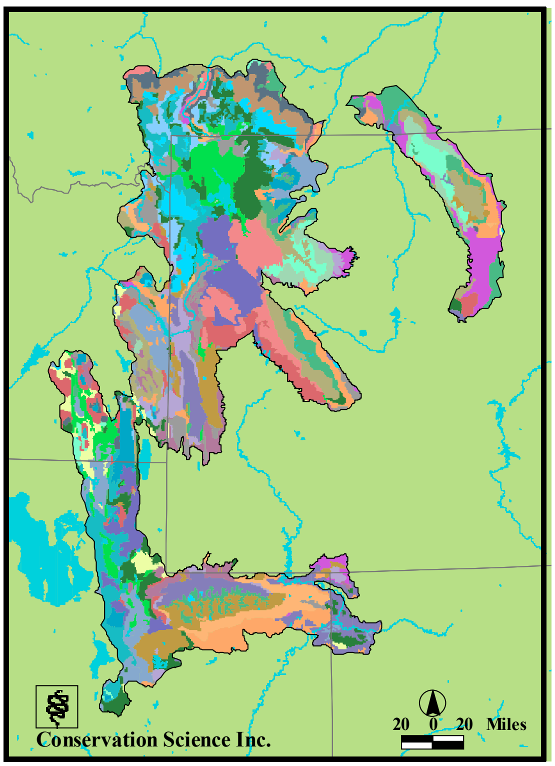


Figure 4. UWRM physical habitat types.

We performed a gap analysis to judge how well the existing system of protected areas represents regional physical habitat types. We also combined GAP vegetation and physical habitat types (i.e., stratified vegetation types by physical habitats). To streamline the list of combined inputs and reduce noise, we dropped any combinations where the physical habitat types made up less than 1% of the total area of the GAP vegetation type, resulting in 723 combinations. We then used SITES to develop portfolios that would protecting at least 10% of the area of each combined vegetation/abiotic type. We used the sum runs option in SITES to determine how frequently planning units were selected for portfolio solutions to represent physical habitat types, then used that information to determine irreplaceability scores for megasites in our proposed portfolio.

Aquatic Habitats

As defined by Grove et al. (2000:3-6) aquatic ecological systems are:

> dynamic spatial assemblages of ecological communities that 1) occur together in an aquatic landscape with similar geomorphological patterns; 2) are tied together by similar ecological processes (e.g., hydrologic and nutrient regimes, access to floodplains and other lateral environments) or environmental gradients (e.g., temperature, chemical, and habitat volume); and 3) form a robust, cohesive and distinguishable unit on a hydrography map.

As for terrestrial ecosystems, the goal is to identify viable examples of every aquatic ecological system type within an ecoregion and across major environmental gradients. The viability of the biological communities associated with a given system is often dependent upon linkages to other systems. This does not necessarily mean that entire watersheds must always be identified as portfolio sites. Rather, the spatial extent of the sites will be decided in the subsequent site conservation planning process (Mary Lammert, TNC, pers. comm.). Nevertheless, a goal should be to select systems that maintain a high level of internal connectivity and connectivity to other systems within the larger drainage network.

We applied two levels of aquatic habitat classification: 1) aquatic macrohabitats, identified at the stream reach level; and 2) aquatic ecological systems, identified at the watershed to basin level. Both classifications utilized four components: 1) stream size (headwater to large river; 2) elevation (low to alpine); 3) stream gradient (low to very steep); and dominant geology (coarse, porous, nonporous). Aquatic macrohabitats are classified by specific portions of the range of each of the four components, e.g., “very steep Alpine headwater in coarse geology.” Aquatic ecological systems, being aggregations of macrohabitats, represent a greater range of component gradients, e.g., “alpine, includes moderate and low gradients, headwater and creek, granitic or volcanic.” See Appendix C for details of the aquatic classifications.

We integrated aquatic ecosystems and nested macrohabitats as combined inputs to SITES, in order to proportionally represent the environmental diversity (predicted biotic diversity) of aquatic ecosystems. To streamline the list of combined inputs and reduce noise, we dropped any combinations where the macrohabitat made up less than 1% of the total length of the aquatic ecological system type. We set goals of representing at least 35% of each combined aquatic habitat type, made 10 runs of 1,000,000 iterations each in SITES, and used the frequency that planning units were selected for the resulting 10 aquatic conservation portfolios as input to our megasite irreplaceability scoring.

<u>Focal Species</u>

We used GIS data on species distribution and habitat characteristics to construct new static models for the region. These results then were compared with those from dynamic models that placed regional population dynamics within a larger multi-regional context. (See Appendix B for a detailed description of focal species methods.) We used data on sightings, specimens, and trapping records of lynx and wolverine from the natural heritage programs of the states of Montana, Idaho, and Wyoming (Groves et al. 1995).

Grizzly bear locations were taken from the vertebrate occurrence database for Wyoming (Wyoming Game and Fish Dept., unpublished data), which contains over 9000 grizzly bear occurrence records, of which 7388 are telemetry locations (Fig. 5). In order to examine change over time in grizzly bear/habitat relationships, we grouped the telemetry data by year and season. We used data on the boundaries of wolf pack territories from fall of 1998 and 2000, as delineated by minimum convex polygons containing reported locations (Ralph Maughan, unpublished data, 1998 data from Houts 2000).

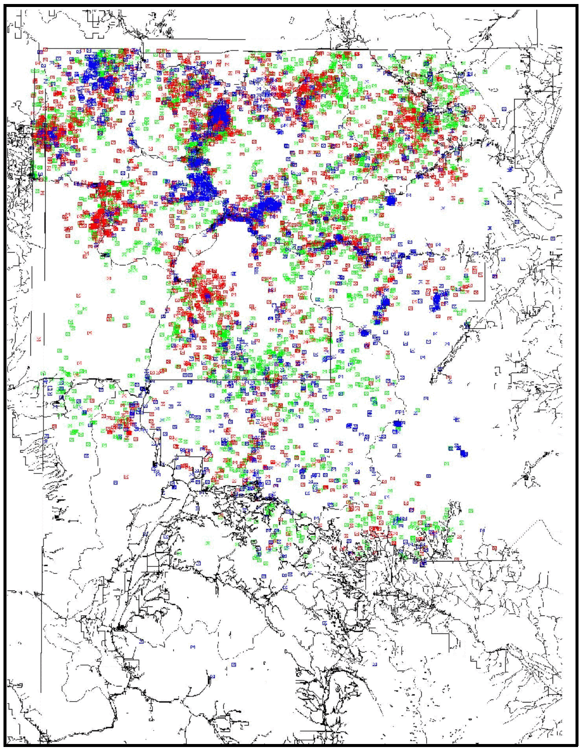


Figure 5. Grizzly bear locations in Yellowstone NP and adjacent areas as recorded in the NPS Grizzly Bear Database and wildlife observation databases up to 1992. Blue points are non-telemetry locations, red points are telemetry locations from pre-August dates, whereas green points are telemetry locations from August and later.

The habitat variables were developed in a GIS format (Appendix B, Table B1). They can be grouped into the five categories of vegetation, satellite imagery metrics, topography, climate, and human-impact related variables. Vegetation cover type data were derived from GIS vegetation layers developed from supervised classification of Landsat Thematic Mapper (TM) satellite imagery by state GAP programs (Redmond et al. 1998, Homer et al. 1997, Merrill et al. 1996). Although we benefitted from these pre-existing maps of vegetation cover type, other vegetation-related variables such as canopy closure and size class were not available for the entire region. "Pseudo-habitat" variables, such as the "tasseled-cap" indices of brightness, greenness, and wetness (Crist and Cicone 1984) that are derived directly from unclassified satellite imagery, are correlated to varying degrees with ecological factors such as net primary productivity (Cihlar et al. 1991, Merrill et al.1993, White et al. 1997) and have proved useful in modeling wildlife distributions (Mace et al. 1999). We derived these indices from the new MODIS imagery, which has a similar spectral resolution as Landsat TM, but is available as weekly composites throughout the year. This allows models to incorporate seasonal changes in resource availability and phenology. We therefore used one midsummer (July19-26, 2000) composite and one composite from early winter (November 8-15, 2000). We derived topographic variables from a digital elevation model assembled at 90 m resolution. We acquired data on mean annual precipitation and snowfall throughout the study area (Daly et al. 1994). Because of their importance as prey for large carnivores, we included elk winter range and bison range as potential variables in the carnivore models.

Road density and human population density may serve as surrogates for the effects of humans on wildlife at the regional scale (Mladenoff et al. 1995, Merrill et al. 1999). GIS data on roads, trails, and railroads were assembled for the study area and grouped into classes based on the degree of expected use. We acquired data on human population at the scale of census blocks (U.S.). The average area of a census block in this region is 4 km^2 when urban areas are included, but most of the area is contained in blocks over 100 km^2 in size. Census data were available for the period 1990-2000. We predicted human population growth from 2000 to 2025 based on growth rates from 1990 to 2000, but adjusted predicted 2025 population to match state-level Census Bureau predictions based on more complex socioeconomic models. Road density was predicted to grow at 1% per year. The one study we area aware of that documents change in road density in a similar Rocky Mountain landscape in Colorado (Theobald et al. 1996) found increases of about 2% per year.

Static Habitat Suitability Models

We used multiple logistic regression to compare habitat variables at telemetry or sighting locations with those at random points or, alternatively, random points falling within occupied territories with those points falling outside those areas (Hosmer and Lemeshow 1989). A large set of alternate multivariate models was constructed and evaluated with diagnostic statistics (Schwarz 1978). We also considered interpretability and field knowledge of the species when choosing among competing models. Because many candidate models were considered, the multiple regression analysis should be considered exploratory. Predicted habitat values can be seen as map-based hypotheses subject to refinement and validation by future survey data (Murphy and Noon 1992, Carroll et al. 1999). The spatial correlation structure of wildlife distribution data was modeled with a moving-average function that assigns to each cell the mean value of the attributes within a surrounding circular window. We used the coefficients from the final model to calculate a resource selection function (RSF) $w(x)$ for used (occurrences) and available (random) resources (Manly et al. 1993, Boyce and McDonald 1999).

Dynamic Population Models

We performed population viability analyses using the program PATCH (Schumaker 1998). PATCH links the survival and fecundity of individual animals to the GIS data on mortality risk and habitat productivity measured at the location of the individual or pack territory. The model tracks the demographics of the population through time as individuals are born, disperse, and die, predicting population size, time to extinction, and migration and recolonization rates.

PATCH ignores intra- and inter-species interactions and focuses instead on the ability of a landscape to promote or preclude population persistence. Territories are allocated by intersecting the GIS data with an array of hexagonal cells. The GIS maps are assigned weights based on the relative fecundity and survival rates expected in the various habitat classes. Survival and reproductive rates are then supplied to the model as a population projection matrix. The model scales the matrix values based on the hexagon scores, with lower scores translating into higher mortality rates and lower reproductive output.

The model produces tabular outputs such as population size as a function of time and extinction probability. It also records spatial data such as the occupancy rates of each breeding site present in the landscape, which then can be compared with density estimates gathered in the field. The model allows the landscape to change through time. This permits the user to quantify the consequences of landscape change for population viability, examine changes in vital rates and occupancy patterns that might result from habitat loss or fragmentation, and predict source and sink habitats within a landscape.

Dynamic viability modeling for the various carnivore focal species began with development of the GIS data on habitat suitability. Two types of models were used to approximate habitat suitability, depending on the data available on demography and distribution. We used regional-scale conceptual models to produce PATCH input maps for fecundity and survival for grizzly bear and gray wolf. PATCH predictions using this framework have been validated with an independent grizzly bear survey data set from British Columbia (Mowat and Strobeck 2000).

The wolverine and lynx are less well known as to demography and habitat use, but have readily-available regional data on their distribution, in the form of sighting or trapping locations (Carroll et al. 2001a). For these species we developed multi-regional RSFs for input into the PATCH model. The RSF models predict distribution, which is a composite result of survival and fecundity in different habitats. Although the link from RSFs to fecundity and survival must be made based on species knowledge, we believe that for these poorly known species, RSF-based estimates are still superior to those from conceptual models.

General Structure of Dynamic Models

The PATCH model requires inputs in the form of a demographic matrix and parameters estimating territory size, dispersal distance, search behavior, and site fidelity (Appendix B, Table B2). The demographic parameters used in the PATCH Leslie matrix represent rates from optimal habitat. Because PATCH scales demographic rates to habitat quality, most territories will have survival and fecundity rates much lower than those shown here. Fecundity is reported as females per adult female, or per pack for the wolf. Year-to-year variation in fecundity and mortality (termed environmental stochasticity) was also incorporated. In the case of the wolf, we modified PATCH by allowing territory holders to be social rather than solitary.

One thousand simulations were performed for each model scenario to quantify stochastic variability in the outcomes. Our mapped simulation results are equilibrium predictions, in that current predictions depict the current "carrying capacity," or the capacity for an area to support a carnivore species over 200 years. Therefore, areas such as central Idaho will exhibit current capacity to support the extirpated grizzly bear, and some rapidly developing areas will show no long-term ability to support their current complement of species.

We modeled landscape change scenarios that incorporated estimates of potential change in human-associated impact factors (e.g., roads and population) during the period 2000-2025. They did not include vegetation change except indirectly in the case of the lynx. These scenarios included 1) current conditions; 2) human population as of 2025, with increased road development on private and non-protected public lands; and 3) human population as of 2025, with increased road development on private lands only.

As noted, the results of the static habitat models for the focal species were incorporated prospectively in the SITES portfolio selection. As a retrospective analysis, we compared SITES solutions that included focal species with results from the PATCH model to assess whether SITES solutions adequately insured population viability and if not, what additional areas were suggested by the PATCH model. Two types of comparisons were used: 1) Megasites selected by SITES were prioritized as to their irreplaceability and vulnerability in the PATCH output by overlaying megasite boundaries on the PATCH results. Irreplaceability in this context is the relative value of an area as source habitat. Vulnerability is measured as the predicted decline in demographic value (lambda = population growth rate) over the next 25 years. Areas identified in this step might include sink habitat that is of only moderate RSF value, but protection of which would greatly enhance population viability by reducing mortality rates of animals dispersing from adjacent high-quality habitat. 2) We also ran the PATCH model on landscapes that included additional protection and restoration of megasites in the selected portfolio to assess more accurately the effects of the portfolio on species viability. Even when set to maximize contiguity of selected planning units, SITES cannot ensure that functionally connected networks are selected. The PATCH model, however, may identify new areas that are important for connectivity.

Expert Assessment

Quantitative data on which to evaluate conservation options are always limited. We sought to apply rigorous, objective measures of conservation value whenever possible, recognizing that a quantitative assessment would need to be supplemented by expert opinion. As noted by Groves et al. (2000: 4-2): "Experts provide valuable and often previously undocumented information on targets, sites, threats, and feasibility. Involvement of experts can be a strategic method of developing meaningful partnerships, receiving peer reviews, and gaining acceptance and credibility for the portfolio." Groves et al. (2000: 4-2) also point out that "expert involvement can range from one-on-one interviews to large meetings depending on the needs and capacity of ecoregional planning teams." We chose a combined approach of one-on-one interviews during early phases of this work, followed by workshops to evaluate the draft results.

Expert opinion was sought to provide validation of heritage data and other published sources and to expand the overall knowledge base. George Wuerthner, an authority on the natural history and ecology of the region, identified a wide range of experts on various aspects of the UWRM, then visited and interviewed these experts. Interviews were conducted during late 1999-2000 throughout the study region. People contacted included federal and state agency biologists, university faculty, staff of environmental groups and others with specific knowledge of the region's biological attributes (Table 1).

Interviews were open-ended and varied considerably. However, the process followed this general sequence:

- The process began with discussion of the person's qualifications and knowledge of the region to find out how long they had been in the area, as well as to learn something of their area of interest or job responsibilities.

- Next, the interview sought to determine basic information on habitat quality of the areas with which the expert was familiar. For example, if speaking with a fishery biologist, George would ask about the water quality and physical attributes of the watershed.

- The status of the species or communities in question was next accessed. Again, using the fish example, George might inquire whether streams and riparian areas were properly functioning. Next he would try to determine the status of rare or sensitive species, including population trends and distribution.

- Finally, experts were asked for their opinion on threats or impacts to the particular species or communities under discussion, the kinds of monitoring and survey efforts that were on-going or planned, and any management efforts being implemented to improve habitat conditions for the species or area.

Immediately after our draft report was produced, our team participated in two workshops to evaluate alternative portfolios and identify the next steps for conservation of priority areas. The first workshop was organized by the Greater Yellowstone Coalition and held April 5-6, 2001, in Bozeman, Montana. This workshop concentrated on the GYE. The second workshop was organized by the Wyoming Field Office of The Nature Conservancy and held April 9-10, 2001 in Lander, Wyoming. This workshop examined the entire UWRM ecoregion, of which the GYE is the northwestern part. Experts in the workshops evaluated alternative portfolios and, based on their knowledge of specific areas, assigned or revised vulnerability scores for particular megasites.

Table 1. Experts interviewed by George Wuerthner during the course of this study.

Alt, Kurt—Biologist--MDFWP—Bozeman, Montana
Aspinall, Richard—GIS specialist, Montana State University, Bozeman, Montana
Bayless, Shawn—Biologist FWS, Lander, Wyoming
Beauvais,Gary —Natural Diversity Program, Laramie, Wyoming
Bennyfield, Pete—Beaverhead NF Dillon, Montana
Blackwell, Boyde—Wildlife Manager, Utah Division of Wildlife, Salt Lake City, Utah
Bradshaw, Bill—Fish Biologist, Wyoming Game and Fish, Sheridan, Wyoming
Bremer, Jim—Beaverhead NF, Dillon, Montana

Brown, Jan—Director, Henry's Fork Foundation, Ashton, Idaho
Browning—Fish Biologist, Beaverhead NF, Dillon, Montana
Bryant, Mike—Refuge Manager, Browns Park NWR, Colorado
Byorth, Patrick—Fish Biologist, MDFWP, Bozeman, Montana
Camenzind, Franz—Jackson Hole Conservation Alliance, Jackson, Wyoming
Capurso, Jim—Biologist, Targhee NF, Ashton, Idaho
Cerovski, Andrea—Non-game biologist, Wyoming Game and Fish, Lander,Wyoming
Chasten, Keith—Forester—BNTF, Kemmerer, Wyoming
Christiansen, Tom—Biologist, Wyoming Game and Fish, Green River, Wyoming
Compton, Brad—Game Biologist, Idaho Fish and Game, Pocatello, Idaho
Copeland, Holly—TNC, Lander, Wyoming
Copeland, Jeff—Biologist, Idaho Fish and Game, Idaho Falls, Idaho
Crabtree, Bob—Biologist, Yellowstone Ecosystem Studies, Bozeman, Montana
Craighead, Lance—Biologist, American Lands, Bozeman, Montana
Danberg, Carol—Refuge Manager, Seedskadee NWR, Wyoming
Despain, Don—Botanist, Montana State University, Bozeman, Montana
Dixon, Bev—Biologist, Gallatin NF, Bozeman, Montana
Dorsey, Lloyd—Wyoming Wildlife Federation, Jackson, Wyoming
Eky,Bob—Regional Director, The Wilderness Society, Bozeman, Montana
Emmerich, John—Wyoming Game and Fish, Cody, Wyoming
Fertig, Walt—Wyoming Natural Diversity Laramie, Wyoming
Fointane, Joe—Biologist, FWS, Helena, Montana
Fouty, Suzanne—Stream geologist, U of Oregon, Eugene, Oregon
Freilich, Jerry—formerly with TNC in Lander, Wyoming
Furmann, Bob—Biologist, Yellowstone NP, Mammoth, Wyoming
Gaillard, Dave—Predator Conservation Alliance, Bozeman, Montana
Garrott, Bob—Biologist, Montana State University, Bozeman, Montana
Gerard,Larry—Biologist, BLM, Buffalo, Wyoming
Gipson, Rob—Wyoming Game and Fish, Jackson, Wyoming
Glick, Dennis—Private Lands Specialist, GYC, Bozeman, Montana
Golden, Harold—Biologist, Bighorn NF, Sheridan, Wyoming
Gomez, Danny—Refuge Manager, Red Rock Lakes NWR, Lima, Montana
Graumlich, Lisa—Climatologist, Montana State University, Bozeman, Montana
Greswell, Bob—Fish Biologist, Oregon State University, Corvallis, Oregon
Hall, Bernie—Conservation Director, TNC, Helena, Montana
Hammin, Ken—Biologist, MDFWP, Bozeman, Montana
Hammond, Gary—Big game biologist, MDFWP, Dillon, Montana.
Hansen, Andy—Biologist, Montana State University, Bozeman, Montana
Heilig, Dan—Wyoming Outdoor Council, Lander, Wyoming
Hilderbrand, Bob—Fish Biologist, U of Maryland formerly with TNC in Utah
Houston, Ken—Ecologist, Shoshone NF, Cody, Wyoming
Hoyt, Marv—GYC-Idaho Falls, Idaho
Hudelson, Ralph—Fish Biologist, Wyoming Game and Fish, Jackson, Wyoming
Jellison, Bert—Habitat biologist, Wyoming Game and Fish, Sheridan, Wyoming

Jemenez, Mike—FWS, Lander, Wyoming
Kaeding, Lynn—Fish Biologist, FWS, Bozeman, Montana
Karh, Trish—Idaho Science Director, TNC, Ketchum, Idaho
Keith, Robert—Fishery Biologist, Wyoming Fish and Game, Rock Springs, Wyoming
Kendall, Kate—Grizzly bear biologist, Glacier NP, West Glacier, Montana
Klaus, Marion—Biologist, Sheridan Community College, Sheridan, Wyoming
Lamment, Mary—TNC Aquatics Specialists, Chicago, Illinois
Lamont, Susan—Resource specialist, Gallatin NF, West Yellowstone, Montana
Lemke, Tom—Biologist, MDFWP, Livingston, Montana
Lichtman, Pam—Assistant Director, Jackson Hole Conservation Alliance, Jackson, Wyoming
Littell, Jeremey—Montana State University, Bozeman, Montana
Lockwood, Ron—Biologist, Wyoming Game and Fish Kemmerer, Wyoming
Luce, Bob—Wyoming Game and Fish, Lander, Wyoming
Maughen, Ralph—Idaho State University, Pocatello, Idaho
May, Bruce—Biologist, Gallatin NF, Bozeman, Montana
McKeneaney, Terry—Bird Biologist, Yellowstone NP, Mammoth, Wyoming
McKnight, Ron—Biologist, Wyoming Fish and Game, Cody, Wyoming
Mcwhethers, Doug—Biologist, Wyoming Game and Fish, Pinedale, Wyoming
Meis, Rick—Activist, American Lands, Bozeman, Montana
Mier, Aaron—Biologist, BLM, Buffalo, Wyoming
Miller, Steve—GIS specialist, Yellowstone NP, Mammoth, Wyoming
Minshall, Wayne—Stream ecologist, Idaho State University, Pocatello, Idaho
Mladenka, Greg—Stream ecologist, Idaho Environmental Dept., Pocatello, Idaho
Neales, Carla—American Lands, Bozeman, Montana
Oakleaf, Bob —Biologist, Wyoming Game and Fish, Lander, Wyoming
Oiver, George—Ecologist, Utah Division of Wildlife, Salt Lake City, Utah
Patla, Deb—Amphibian specialist, Idaho State University, Driggs, Idaho
Petersburg, Stephen—Biologist, Dinosaur NM, Colorado
Peterson, Chuck—Amphibian specialist, Idaho State University, Pocatello, Idaho
Primm, Steve—Biologist, Ennis, Montana
Reed, Tom—Biologist, Red Rock Lakes NWR, Montana
Reihart, Dan—Biologist, Yellowstone NP, Wyoming
Remmex, Ron—Fishery biologist, Wyoming Game and Fish, Rock Springs, Wyoming
Rice, Peter—Weed expert, U of Montana, Missoula, Montana
Rodman, Ann—GIS specialist, Yellowstone NP , Wyoming
Rondeau, Renee TNC—Boulder, Colorado
Rosentretor, Roger—Botanist, BLM, Boise, Idaho
Rudd, Bill—Biologist, Wyoming Game and Fish Rock Springs, Wyoming
Ruzycki,Jim—Fish Biologist, Yellowstone NP, Mammoth, Wyoming
Ryder, Tom—Biologist, Wyoming Game and Fish, Lander, Wyoming
Schmidt, John—Sierra Club, Pocatello, Idaho
Schullery, Paul—Natural Resource Historian, Yellowstone NP, Wyoming
Scott, Michael—Program Officer, GYC, Bozeman, Montana
Scully, Dick—Idaho Fish and Game, Pocatello, Idaho

Shepard, Brad—Fish Biologist, MDFWP, Bozeman, Montana
Skates, Dave—Fish Biologist, FWS, Lander, Wyoming
Skeele, Tom—Predator Conservation Alliance, Bozeman, Montana
Smith, Bruce—Biologist, National Elk Refuge, Wyoming
Sparks, Jim—Biologist, Gallatin NF, Big Timber, Montana
Steward, Shawn—Biologist, MDFWP, Red Lodge, Montana
Succi, Don—Biologist, Custer NF, Billings, Montana
Taylor, Meredith—Wyoming Outdoor Council, Lander, Wyoming
Taylor, Tory—Wyoming Wildlife Federation, Dubois, Wyoming
Thatcher, Tony—DTM Data Bases, Bozeman, Montana
Torbit, Steve—Biologist, National Wildlife Federation, Denver, Colorado
Tuhy, Joel—Ecologist, TNC, Moab Utah
Tyers, Dan—Biologist, Gallatin NF, Gardiner, Montana
Van Kirk, Rob—Fish Biologist, Idaho State University, Pocatello, Idaho
Varley, John—Biologist, Yellowstone NP, Mammoth, Wyoming
Varley, Nathan—Biologist, Mammoth, Wyoming
Vincent, Dick—Fish biologist, MDFWP, Bozeman, Montana
Weaver, Tad—Botanist, Montana State University, Bozeman, Montana
Welch, Mike—Biologist, Utah Division of Wildlife, Salt Lake City, Utah
Whipple, Jennifer—Botanist, Yellowstone NP, Mammoth, Wyoming
Whitfield, Mike—Teton Valley Land Trust, Driggs, Idaho
Whitlock, Cathy—Biogeographer, U of Oregon, Eugene, Oregon
Wilcox, Louisa—Sierra Club Grizzly Bear Task Force, Bozeman, Montana
Williams, Jamie—Montana State Director, TNC, Helena, Montana
Wisman, Ron—Beaverhead NF Ennis, Montana
Zubik, Ray—Fish Biologist--Shoshone NF, Cody, Wyoming

Irreplaceability versus Vulnerability of Megasites

We aggregated planning units (modeled 6th-level watersheds) into megasites for purposes of evaluation and priority setting. Megasites comprised generally contiguous planning units selected as the best (i.e., “best runs” with lowest cost) of the SITES sum runs. Other planning units were evaluated as potential connectivity zones linking megasites, but these units were not included in the portfolio per se. We used the U.S. Geological Survey 4^{th-}level watershed coverage and topographic maps to inform these decisions, with most site boundaries set by watershed boundaries and the location of mountain ranges and other topographic features. These larger sites are areas that “make sense” in terms of geography, land ownership, or other factors that must be considered in the process of implementing a conservation plan. We strove to keep the number of megasites reasonably low in order to allow comparative scoring and priority-setting.

Approximately 94 planning units totaling 383,000 ha (946,000 acres) selected by the SITES sum runs lie outside of our designated megasites. These areas are often valuable as linkages, buffer zones, or areas where specific habitat types not protected well by portfolio sites might be represented, yet their site-specific values are too low for us to include them within megasites.

A key concept in conservation planning is irreplaceability (Pressey et al. 1994, Margules and Pressey 2000, Pressey and Cowling 2001). Irreplaceability provides a quantitative measure of the relative contribution different areas make to reaching conservation goals, thus helping planners choose among alternative sites in a portfolio. As noted by Pressey (1998), irreplaceability can be defined 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 and explicit conservation goal are narrowed if an area is not conserved. A site with an irreplaceability value of 100 for a particular class of targets is essential to meeting a particular goal; if that site is destroyed, the goal cannot be attained. An example might be a site that holds the only known occurrence of a species in the ecoregion, the world, or whatever other geographic area is under consideration. A site with an irreplaceability value of 0 has essentially infinite replacements.

The irreplaceability values of sites will vary depending on the specific targets and goals that are set. One site might be irreplaceable for meeting the goal of protecting all viable occurrences of G1 species, but completely replaceable for meeting the goal of conserving the highest quality habitat for focal species (i.e., because its habitat suitability value for those species is close to zero). Because our assessment considers multiple values of sites and attempts to achieve a broad set of conservation goals, we assigned irreplaceability values to sites based on 9 criteria:

1) Contribution to the goal of protecting at least 10 viable occurrences (or 100% for G1/G2 species) of all imperiled, local-scale (class 1) species in the ecoregion.

2) Contribution to the goal of protecting at least 10 viable occurrences (or 100% for G1/G2 species) of vulnerable and declining (class 2) bird species in the ecoregion.

3) Contribution to the goal of protecting habitat capable of supporting 50-70% of the population of each focal species (class 3) that currently could be supported in the ecoregion, as identified by habitat suitability modeling (i.e., 50% for elk, 70% for carnivores).

4) Contribution to the goal of maintaining viable populations (regionally and inter-regionally) of focal species over time, as determined by the PATCH dynamic model. Scores were an average of predicted lamda (population growth rate) values for grizzly bear, wolf, and wolverine, weighted by the likelihood that a site was occupied by the species.

5) Contribution to the goal of protecting at least 10 (or 100% for G1/G2 species) viable occurrences of coarse-scale and regional-scale aquatic species (class 4) in the eco region.

6) Contribution to the goal of protecting 100% of all viable occurrences of G1/G2 plant communities and at least 10 of the occurrences of other plant communities of high conservation interest (class 5) in the ecoregion.

7) Contribution to the goal of representing at least 35% of the area of each wetland vegetation type and at least 25% of the area of each other vegetation type in the ecoregion.

8) Contribution to the goal of representing at least 10% of the area of each combined vegetation and abiotic (geoclimatic) habitat type in the ecoregion.

9) Contribution to the goal of representing at least 35% of the length of each aquatic (stream) habitat type in the ecoregion.

Each megasite was scored 0-10 for each of the 9 criteria. For criteria 1-3 and 5-9, the number of times (out of 10) individual planning units were selected in SITES sum runs were averaged and the area-weighted mean used as the score for each megasite. For criterion 4, entire megasites were scored as units. A total irreplaceability score was calculated for each megasite by summing the scores from the 9 criteria and rescaling the sums to range from approximately 1 to 100.

Another key consideration in conservation planning is threat or vulnerability (Margules and Pressey 2000). Based on expert opinion about the threats faced by each megasite, and taking into consideration quantitative threat data (e.g., human population growth, development trends), we assigned a vulnerability score of 0-100 to each megasite. Preliminary vulnerability scores were revised by participants in the workshop in Lander, and those revised scores were rescaled to range from approximately 1 to 100. Megasites were then plotted on a graph of irreplaceability (y-axis) versus vulnerability (x-axis) and the graph divided into four quadrants, following the procedure of Margules and Pressey (2000). The upper right quadrant, which includes megasites with high irreplaceability and high vulnerability, comprises the highest priority sites for conservation. This top tier of megasites is followed by the upper left and lower right quadrants (2nd and 3rd tiers, which could be ordered differently depending on needs of planners), and finally, by the lower left quadrant, comprising megasites that are relatively replaceable and face less severe threats. Within quadrants, megasites were ranked for conservation priority using the sum of their irreplaceability and vulnerability scores.

RESULTS

Proposed Portfolio

Our proposed portfolio (Fig. 6) is the “best run” SITES result that included all components of the three tracks (special elements, representation, and focal species) using the goals listed above. The 43 megasites in the portfolio (described in detail in Appendix D) range in size from 18,332 to 1,225,041 acres (average size 235,485 acres) and total 10,125,847 acres (37% of the UWRM). Private lands constitute 34% (3.4 million acres) of the total portfolio area. The connectivity zones shown in Fig. 6 are designed to link megasites into a functional network. These 62 zones, based largely on elk winter habitat and topographic features, include 106 planning units and constitute 1,313,037 acres. Although not part of the portfolio per se, we recommend that development and other sources of fragmentation be minimized within these zones until detailed studies of wildlife movement allow critical movement routes to be identified.

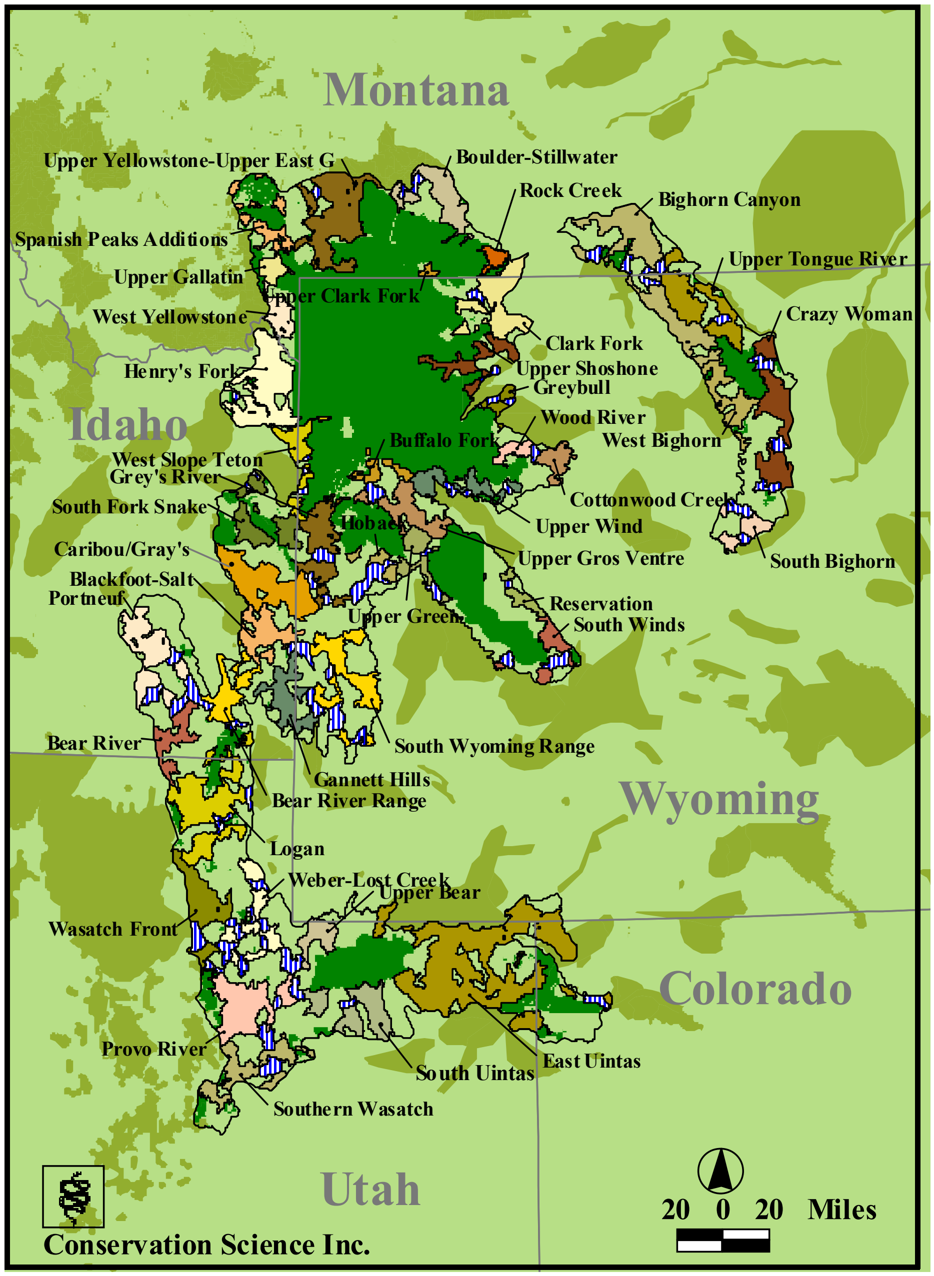


Figure 6. Proposed portfolio of conservation sites. Existing protected areas dark green, proposed connectivity zones hatched blue, adjacent ecoregion portfolios in background (olive).

Existing protected

areas (totaling 8,151,000 acres) combined with our proposed portfolio of megasites would bring the total protected area in the UWRM to18,277,000 acres, nearly 68% of the ecoregion. That protected areas network would encompass nearly 86% of special element occurrence, critical habitats of focal species, and ecological systems (vegetation, aquatic habitats, and vegetation and physical habitats combined) within the ecoregion (see later section of results: Irreplaceability versus Vulnerability).

Special Elements

The proposed portfolio captures 100% of the documented G1 and G2 species and community occurrences in the UWRM, compared to only 42% in existing protected areas. On average, protection of element occurrences for the four classes of special elements would increase by over 51% with this portfolio.

There are 801 local-scale species (Appendix A, Class 1) occurrences in our proposed portfolio, which when added to the 704 such occurrences in existing protected areas, capture 1505 of the 1648 local-scale species occurrences in the UWRM (91.3%). There are 181 G1 or G2 occurrences included in the 801. Only about 16% of the Class 1 occurrences in the portfolio are animals (125 of the 801). Apart from a questionable record for black-footed ferret (*Mustella nigripes*), the other two G1 local-scale animal species are molluscs: Eureka mountainsnail (*Oreohelix eurekensis*) and Green River pebblesnail (*Fluminicola coloradoensis*). The three G2 local-scale animal species are all molluscs: deseret mountainsnail (*Oreohelix peripherica*), lyrate mountainsnail (*Oreohelix haydeni*), and southern Bonneville springsnail (*Pyrgulopsis transversa*). The other Class 1 animal species occurrences (all G3 or lower) included in the proposed portfolio consist of 11 mammal species, four amphibians, four molluscs, three snakes, one crayfish, and one butterfly. Class 1 plant occurrences in the proposed portfolio include nine G1 species, 24 G2 species, and 150 species ranked G3 or lower.

Our proposed portfolio captures occurrences of 101 local-scale species that are not recorded in existing protected areas, including ten G1 species (black-footed ferret, Eureka mountainsnail, Green River pebblesnail, Gibben's beardtongue [*Penstemon gibbensii*], Graham's columbine [*Aquilegia grahamii*], Huber peppergrass [*Lepidium huberi*], Maguire primrose [*Primula maguirei*], repand twinpod [*Physaria repanda*], rock hymenoxys [*Hymenoxys lapidicola*], and Wasatch draba [*Draba brachystylis*]) and ten G2 species. There are 143 uncaptured occurrences of 34 Class 1 species (all with rank of G3 or lower), and all are of species recorded within existing protected areas or elsewhere in the proposed portfolio.

There are 271 bird species (Class 2) occurrences in the proposed portfolio, which combined with the 145 Class 2 occurrences in existing protected areas capture 416 (86.5%) of the 481 bird species occurrence records in the GYE. The single G1 bird species represented in the proposed portfolio is the whooping crane (*Grus americana*), and consists of non-breeding observations, which are assumed to be important migratory stopover areas. There are no G2 or G3 bird species in the proposed portfolio, and there are 42 bird species ranked G4 or lower. Twenty G4 and G5 bird species captured by the proposed portfolio are not recorded as occurring in existing protected areas. The 65 uncaptured Class 2 occurrences (all for species ranked G4 or lower) are for bird species recorded within existing protected areas or elsewhere within the proposed portfolio.

The 18 fish species or subspecies (Class 4) recorded for the UWRM in natural heritage program data include seven G1 species (Bear Lake sculpin [*Cottus extensus*], bonytail [*Gila elegans*], Colorado pikeminnow [*Ptychocheilus lucius*], humpback chub [*Gila cypha*], June sucker [*Chasmistes liorus*], least chub [*Iotichthys phlegethontis*], razorback sucker [*Xyrauchen texanus*]) and one G2 species (roundtail chub [*Gila robusta*]). There are 85 Class 4 occurrences in the proposed portfolio, which when added to the 65 occurrences in existing protected areas capture 61.7% of the 243 occurrences recorded in the UWRM. Eleven fish species or subspecies not recorded in existing protected areas are captured by the proposed portfolio, including four G1 species: Bear Lake chub, Colorado pikeminnow, June sucker, and least chub. The 93 uncaptured Class 4 occurrences are all for Bonneville (*Oncorhyncus clarki utah*), Colorado River (*O. c. pleuriticus*), and Yellowstone (*O. c. bouvieri*) cutthroat trout, all ranked G4T4 and all recorded within existing protected areas or the proposed portfolio.

The 318 plant community occurrences (Class 5) in the proposed portfolio and 227 in existing protected areas capture 100% of the 545 Class 5 occurrences in the UWRM. Six G1 plant communities in the proposed portfolio are not recorded in existing protected areas: cold desert shrublands (*Atriplex confertifolia / Stipa comata*), narrowleaf cottonwood / water birch (*Populus angustifolia / Betula occidentalis*), subalpine fir / buffalo-berry (*Abies lasiocarpa / Shepherdia canadensis*), threesquare bulrush (*Scirpus americanus*), white spruce/bladder sedge (*Picea glauca/Carex utriculata*), and white spruce/softleaf sedge (*Picea glauca/Carex disperma*). In addition, 14 G2 and 49 G3 or lower plant communities in the proposed portfolio are not recorded in existing protected areas. There are no uncaptured Class 5 occurrences.

Representation

Among the three tracks, our proposed portfolio most fully meets conservation goals for ecological systems (Class 6) representation: nearly 97% of Class 6 aquatic, vegetation, and combined vegetation/physical habitat types are included in the portfolio at or above the targeted levels. Because current protected areas total 30% of theUWRM, and our proposed portfolio would increase protected area to nearly 68%, it is not surprising that our representation goals were met and, in most cases, exceeded.

Vegetation

Current protected areas meet our 25-35% representation goals for over 38% of the 44 GAP vegetation types in the UWRM. Our proposed portfolio increases representation to meet 100% of the goals, an increase of over 61%.

Combined Vegetation/Physical Habitats

Current protected areas meet our 10% representation goal for only about 45% of the 723 vegetation/physical habitat types in the region. Our portfolio increases representation to 93.9%, an increase of over 49%.

Aquatic Habitats

There were 561 unique combinations of aquatic macrohabitats and aquatic ecological systems from our aquatic habitat classification that were used in our SITES analyses. Current protected areas meet our 35% representation goal for over 36% of aquatic (stream) habitat types. Our proposed portfolio increases this to almost 98%, an increase of over 60%.

<u>Focal Species: Static Habitat Suitability Models</u>

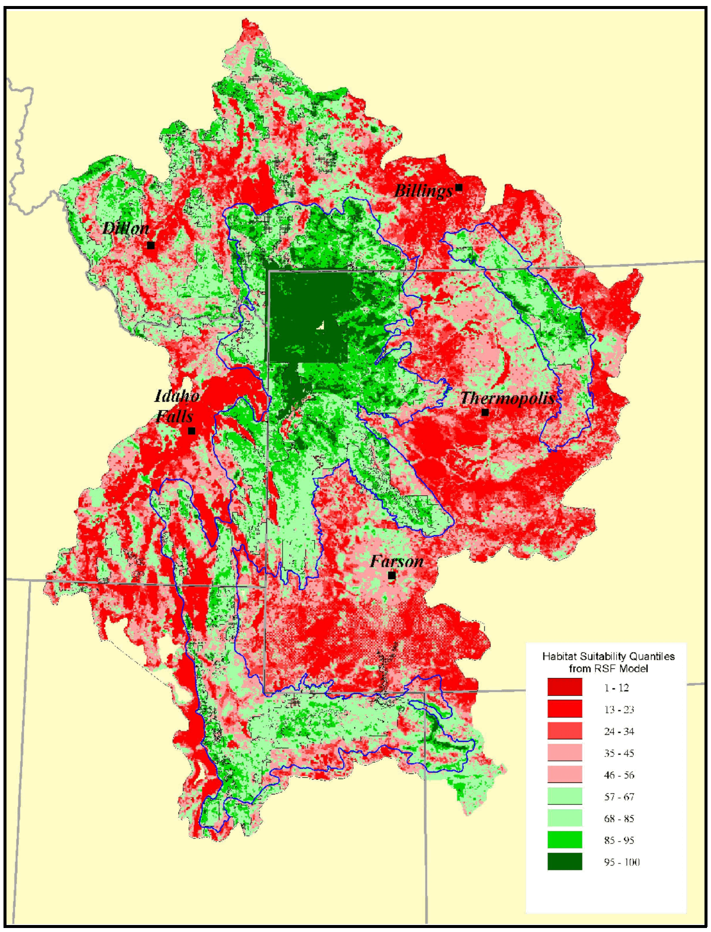


Figure 7. Results of a resource selection function (RSF) model built from telemetry data for grizzly bears in the UWRM region.

Grizzly Bear

Using the full telemetry data set, we selected as an optimal model one that contained the variables for MODIS July brightness and greenness, November brightness, greenness and wetness, slope, elk winter range, road density from the 25 km^2 moving-window, management class (private, general public, wilderness, or park), and interactions between road density and management class and between November brightness and wetness (-2LL = 6916, $\chi^2 = 3569$, df = 16, $p < 0.001$) (Fig. 7). (See Appendix B for details of methodology, including databases).

July wetness was highly correlated with brightness (r = -0.92) which excluded it from the model. All other MODIS tasseled-cap variables were included in most alternate models with low Bayesian Information Criterion (BIC; a model-fitting statistic), attesting to their high explanatory power. The inclusion of indices from both seasons demonstrates the utility of multitemporal data. Grizzly bear locations show a strong negative association with increasing road density in univariate models using both 1:24,000 and 1:100,000 scale roads data. However, multivariate model selection was complicated by the negative correlation between road density and other variables such as elevation, snowfall, and precipitation. Models with low BIC that included the latter variables often resulted in positive coefficients for road density. These models were not chosen because the result of this colinearity problem would have been poor model generality when extrapolated to areas of high road density outside the GYE. This elevation/roads colinearity has been noted in previous work with this data set (M. Boyce, pers. comm.).

Consistent with earlier models (Mace et al. 1999, Boyce and Waller 2000), the greenness index shows a positive coefficient in both seasons. July brightness and November wetness show negative coefficients (similar to results of Boyce and Waller 2000), whereas November brightness shows a positive coefficient, as does its interaction with wetness. Slope shows a positive coefficient.

The variable for management class shows a moderate positive effect of general public versus private lands (the base level). This effect doubles for the comparison between private lands and wilderness and triples for that of private lands versus national park. Road density has a negative coefficient. However, the magnitude of this effect is overshadowed by its interaction with management class. Whereas areas of higher road density show a small additional negative effect on general public lands and a small positive effect on park lands (this could be an artifact of telemetry bias), there is a strong negative interaction effect within wilderness. Road density may be non-zero in wilderness areas due to presence of trails or of roads in adjacent parts of the GIS moving window.

Although minor variation was evident in the structure of optimal models when the telemetry data set was subset by season or decade, the model identified from the full data set was among the best models in these latter cases. Variation between subset models in the values of the coefficients (Appendix B, Table B3) show some suggestive patterns. The positive association with elk wintering habitat is most evident, not surprisingly, in spring, but also in the pre-fire period 1980-1988. Negative association with road density is also most evident in that period. The positive coefficient for the park management class has become weaker with time until it is similar to that for non-park wilderness areas. The interaction of roads and management class suggests higher sensitivity to roads on public lands during spring. The interaction of roads with the park management class is positive except during the period before 1980 (a period of high mortality of habituated bears within the park). The interaction of roads and trails with the wilderness management class has become more strongly negative with time, perhaps reflecting increased hunter-associated mortality.

Wolf

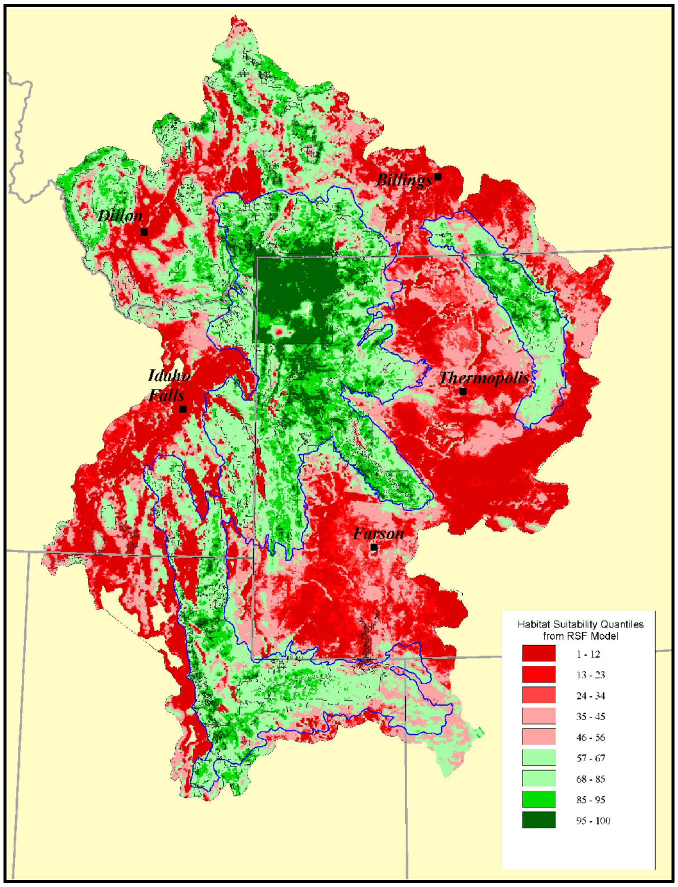


Figure 8. Results of a resource selection function (RSF) model built from pack territory location data for wolves in the UWRM region.

Using pack territory data from both1998 and 2000, we selected an optimal RSF model containing the variables for MODIS July brightness, greenness, and wetness, November wetness, slope, elk winter range, road density from the 25 km^2 moving-window, slope in a quadratic form, snowfall in a quadratic form, and management class (-2LL = 2403, χ^2 = 3528, df = 14, p < 0.001) (Appendix B, Table B4; Fig. 8).

This model, though similar to that selected for the grizzly bear, differs in the strong negative association with slopes of above 20 degrees. The relationship with snowfall becomes negative in the area of highest snowfall (> 1000 cm) in southern Yellowstone National Park and adjacent mountain ranges. The management variable shows general public lands as similar to private lands, with wilderness showing a small positive coefficient and parks a larger one. In general, there is less distinction between management classes than in the grizzly bear model and no significant interaction between roads and management class.

Wolverine

The wolverine RSF model built from Montana/Idaho occurrence data (modified from Carroll et al. 2001a) included variables for MODIS July wetness, snowfall (quadratic), latitude-adjusted elevation, interpolated human population density, and a high road-density threshold (-2LL = 1699, χ^2 = 3180, df = 7, p < 0.001) (Table A5). The new wolverine RSF model built from GYE occurrence data included variables for MODIS July wetness, precipitation (quadratic), latitude-adjusted elevation (quadratic), and management class (-2LL = 1196, χ^2 = 1345, df = 9, p < 0.001) (Appendix B, Table B5, Figure 9).

The wolverine models have poorer predictive power than those of the other focal species. This is consistent with the scarcity of field knowledge of habitat relations for this species. Wolverine are thought to be generalists in relation to vegetation, which may explain why the only tasseled-cap

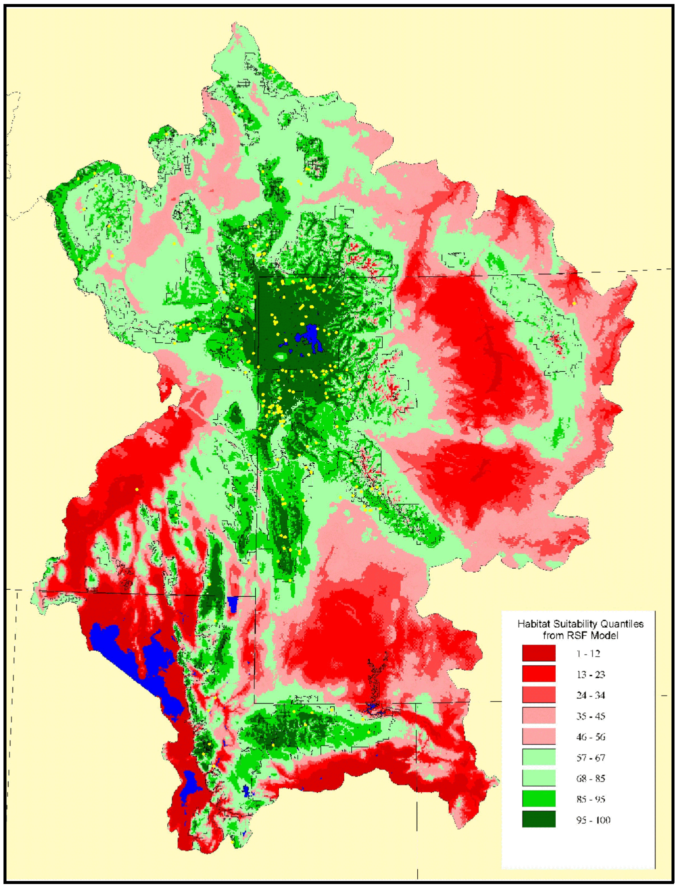
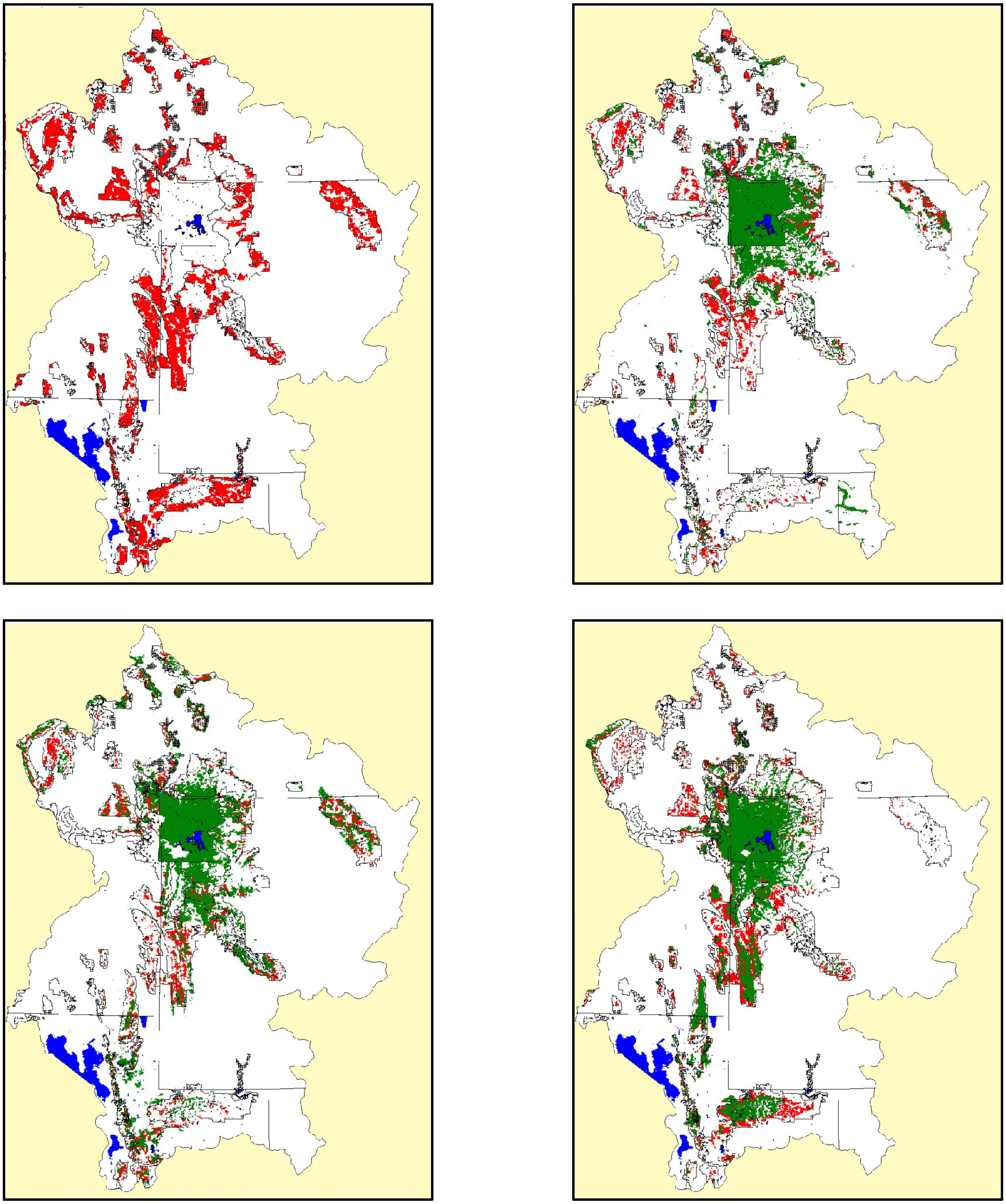


Figure 9. Results of a resource selection function (RSF) model built from occurrence data for wolverines in the UWRM region.

index included in the models (wetness) has a low magnitude and changes sign between the two models. The management effect, showing a positive association with wilderness and especially parks, makes the wolverine model similar to those of the grizzly bear and wolf, rather than other mesocarnivores (Carroll et al. 2001a). Nevertheless, because sightings data is used here, it is plausible that management effect may be influenced by reporting bias (e.g., sightings on private land may be underreported).

Because the models for grizzly bear, wolf, and wolverine include the effects of management category, it may be informative to assess potential effects of changing the management status of areas to enhance carnivore populations. Of particular interest are roadless areas identified in the second federal Roadless Area Review and Evaluation (RARE II) inventory but not currently included in the wilderness system (Fig. 10). The USDA Forest Service granted increased protection to roadless areas in 2000, although some motorized and extractive activities are still permitted and are expected to increase under the current federal administration. Areas with currently high probability of occurrence of grizzly bear, wolf, and wolverine, respectively, are shown in green in Figures 11-13. Areas in red show similarly high suitability in the model if given status equivalent to wilderness. Substantial areas of the UWRM, especially the southern GYE (e.g., Wyoming Range and Caribou National Forest) and northwestern GYE (e.g., Gravellies), but also portions of the Uinta, Wasatch, and Bighorn ranges, show potential for enhancing carnivore populations under this scenario.



Figures 10-13. Areas in red included in RARE II roadless inventory but not currently designated as wilderness (upper left), and areas with high occurrence probability of grizzly bears (upper right), wolves (lower left) amd wolverine (lower right) as predicted by a RSF model under current conditions (green) and if all roadless areas were to receive management equivalent to wilderness designation (red).

Lynx

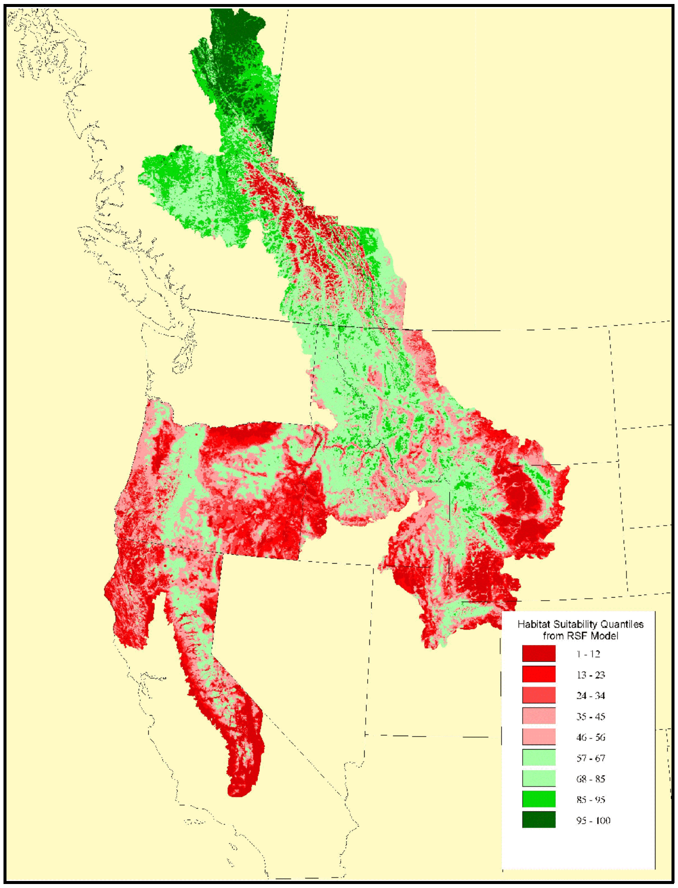


Figure 14. Results of a resource selection function (RSF) model built from occurrence data for lynx in Montana and Idaho and extrapolated to a larger region of western Canada and the United States.

The lynx RSF model built from Montana/Idaho occurrence data (modified from Carroll et al. 2001a) included variables for MODIS July brightness and greenness, latitude-adjusted elevation, topographic complexity, and a low road-density threshold (-2LL = 1340, χ^2 = 3423, df = 6, p < 0.001) (Appendix B, Table B6). For context, an extrapolation of this model to a larger region from the Yukon border southwards is shown in Figure 14. The new lynx RSF model built from GYE occurrence data included variables for MODIS July brightness and greenness, latitude-adjusted elevation (quadratic), lynx vegetation cover types, and management class (-2LL = 966, χ^2 =1045 , df = 10, p < 0.001) (Table B6).

Elk

Elk winter range as delineated by species experts was evaluated as to viability based on human-impact factors, including road density. Areas of wintering habitat with high potential viability (low road density) on private lands were identified for potential inclusion in portfolios. The elk winter range predictive model included variables for November brightness, greenness, and wetness, transformed aspect, slope (quadratic), topographic complexity, snowfall (quadratic), and precipitation (quadratic). Coefficients of the variables (Appendix B, Table B7) show positive association with well-vegetated areas (high greenness, low brightness) that are somewhat sloping southwest aspects. On a regional scale these areas (Fig. 15) do not overlap strongly with high quality habitat for the large carnivores, largely due to the human-associated factors that restrict carnivore distribution more than ungulate distribution. We used the predictive model to rank the relative potential of expert-opinion based wintering areas and to identify potential wintering areas that were not previously delineated.

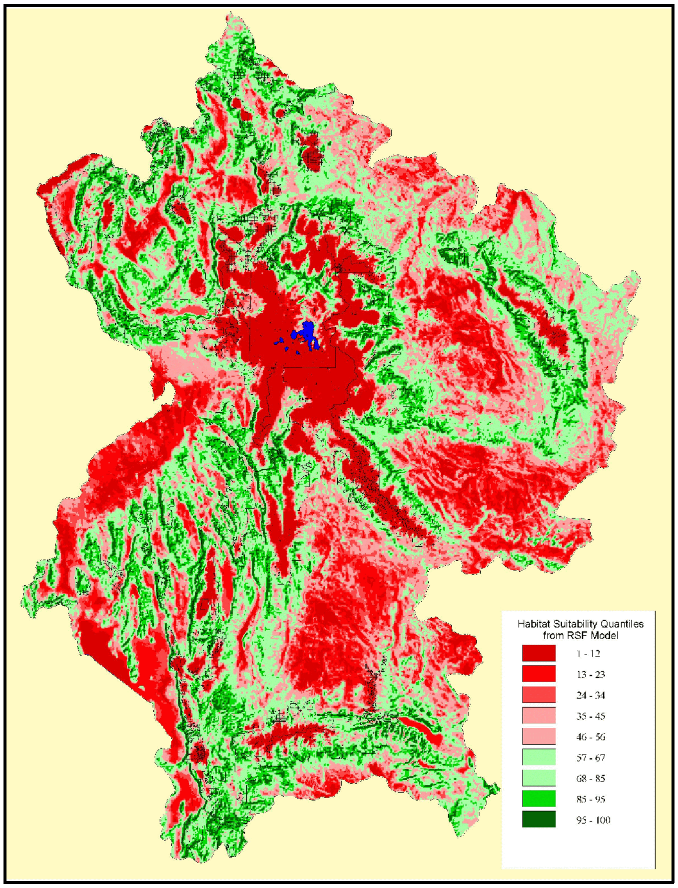


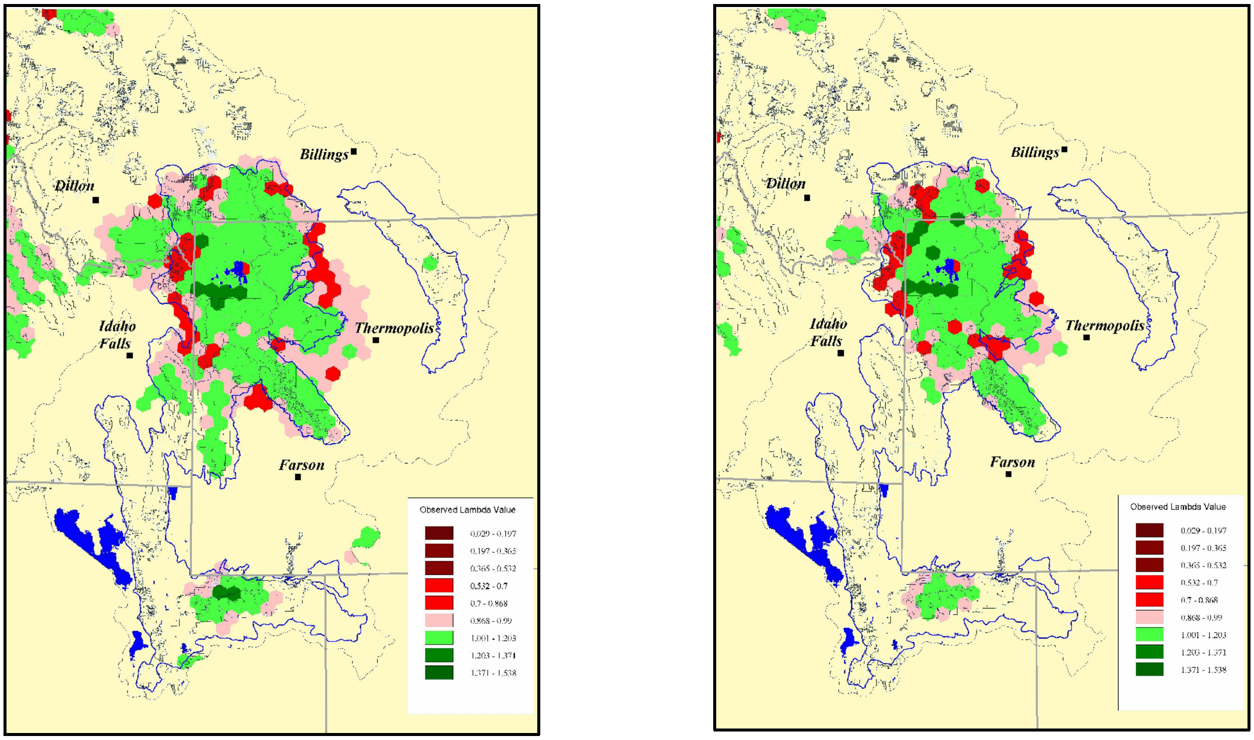
Figure 15. Results of a logistic regression model predicting relative suitability as elk wintering habitat for areas in the UWRM region. The model was built using regional-scale GIS habitat data and areas of elk wintering habitat as delineated by state wildlife agencies and other expert sources.

Focal Species: Dynamic Population Models

We predict that the UWRM, especially the GYE around Yellowstone National Park, will lose a substantial percentage of its carrying capacity for carnivore populations in the next 25 years if current trends continue. The predicted loss ranges from 13.0% for the wolverine to 23.1% for both the wolf and the grizzly bear. If no new road construction occurs on public lands, the loss is reduced by approximately 50%, e.g., to 11.9% for the grizzly bear and 13.0% for the wolf. Although the presence of large core areas such as Yellowstone National Park buffers populations from complete extirpation, changing landscape conditions have strong impacts on both abundance and distribution of these and other carnivore species. The contrast between the types of predictions provided by non-spatial PVAs (e.g., overall extinction probability) and spatial PVAs such as PATCH is striking. Rather than simply preventing regional extinction, the conservation goal is to preserve and enhance well-distributed carnivore populations. Under current landscape conditions, the PATCH model predicts that areas capable of supporting grizzly bears encompass most of the public lands core of the GYE and some private lands along the western edge of the Bighorn basin (Fig. 16a). Wolves could potentially occupy a larger area that is contiguous with the central Idaho population (Fig.18a). Although occasionally dispersal of grizzly bears between the GYE and adjacent regions cannot be ruled out, the GYE grizzly bear population is demographically isolated under most plausible scenarios whereas wolves in the GYE form part of a larger metapopulation.

Grizzly Bear

The potential demographic structure of the GYE grizzly bear population under current conditions assuming the high mortality scenario (Fig. 16a) shows strong source



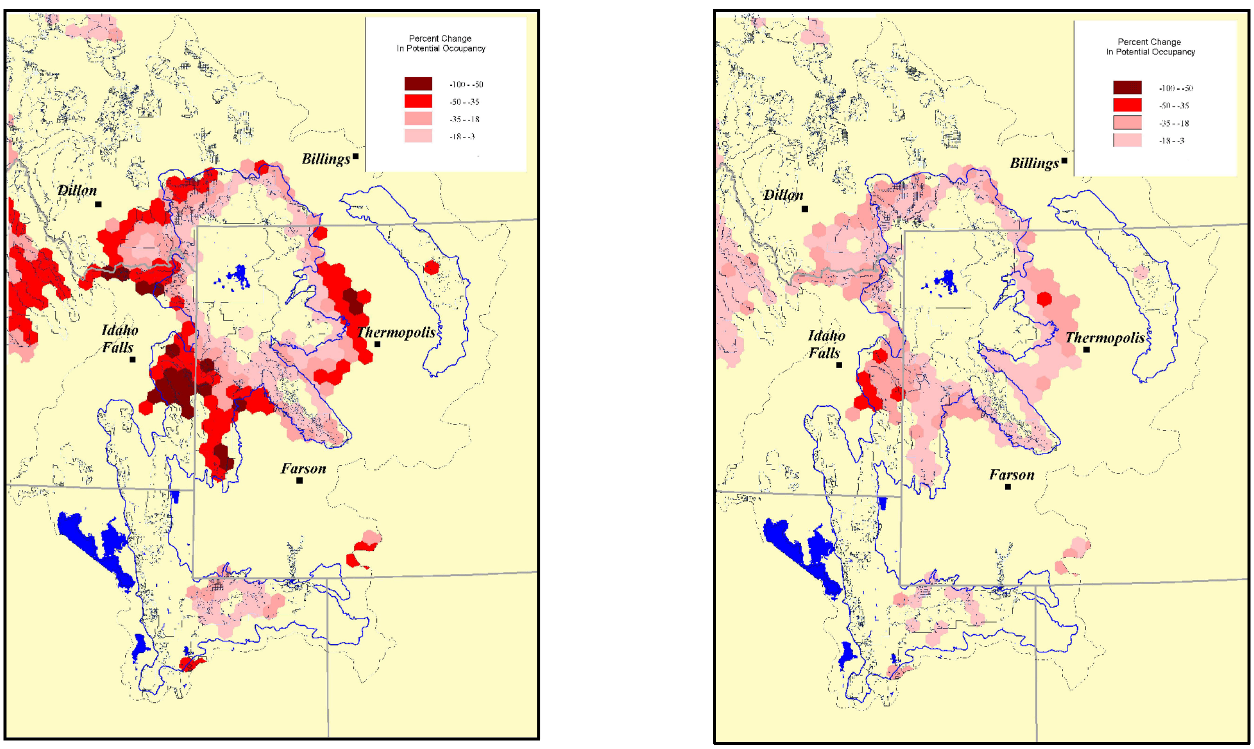
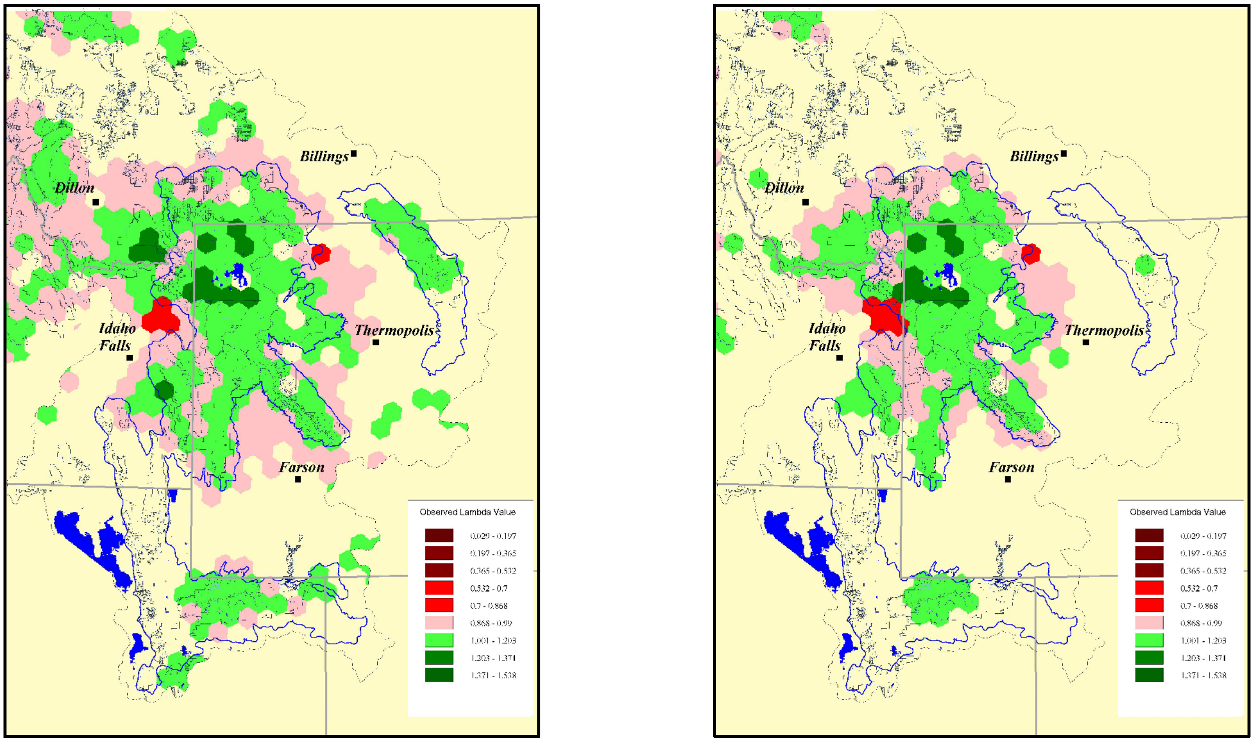


Figure 16 (upper row). Distribution and demographic potential of grizzly bears in the UWRM region under current (a) and future (scenario 2 - road development on both private and public lands)(b) landscape conditions (high mortality parameter set). Figure 17 (lower row). Change in potential grizzly bear distribution between current conditions and future scenario 2 (a) or future scenario 3 (b)(road development on private lands only).



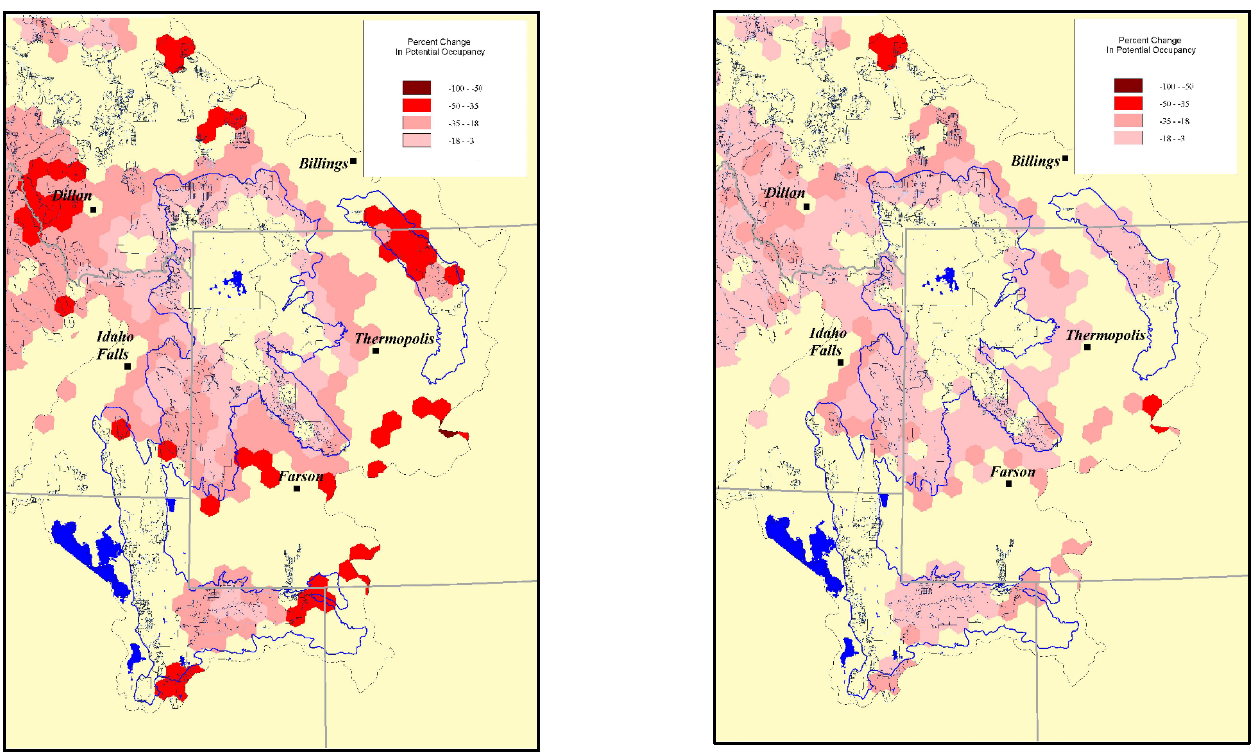


Figure 18 (upper row). Distribution and demographic potential of wolves in the UWRM region under current (a) and future (scenario 2 - road development on both private and public lands)(b) landscape conditions (high mortality parameter set). Figure 19 (lower row). Change in potential wolf distribution between current conditions and future scenario 2 (a) or future scenario 3 (b)(road development on private lands only).

habitat in the areas that encompass most of the current bear distribution (Yellowstone park and the western Shoshone NF). The model suggests that given time, bears could expand into a buffer region that encompasses most of the national forest adjacent to the park, especially on the eastern and southern periphery. This pattern is consistent with recent eastward expansion of the population (Blanchard et al. 1992) and increasing bear occurrences in the western Bighorn basin. Important potential threats to this population expansion under current conditions include sink habitat in the Dunoir valley, Driggs area, below Gardiner, and in the Cody and Red Lodge areas. The Uintas are shown as a potential reintroduction site, although their small area would make this a lower priority than protection of the GYE population.

Under pessimistic future conditions (scenario 2) and high mortality (Figure 16b), core areas of the GYE remain occupied and strong sources, but they are no longer able to support the large areas of peripheral distribution. This is due to degradation of the peripheral habitat and envelopment of the core GYE by a ring of strong sink habitat. The areas showing greatest occupancy loss (Fig. 17a) impinge on the current grizzly bear recovery zone primarily in the north and west. The amount of habitat loss is greatest in the southern and eastern GYE, although much of this area is not currently included within the recovery zone. The areas suffering greatest demographic change from sources to sink habitat generally remain occupied by bears. Lying outside these areas is a ring of sink habitat that becomes vacant as population viability declines. The increase in sink habitat is greater in the GYE than in the adjacent central Idaho recovery area, because protected areas are adjacent to rapidly growing human population centers in the GYE. If habitat degradation does not occur on public lands (scenario 3), a dramatic increase in potential occupancy is evident in the northwestern and southwestern GYE (Fig. 17a vs Fig.17b). The Wyoming range and Gravellies, as peninsular extensions of habitat from the core area, are most sensitive to these changes.

A more optimistic scenario, which assumes bears in lightly-roaded areas (primarily national forest lands) may have survival closer to that in parks, results under current conditions for bears occupying more of the GYE periphery, especially in the Gravellies, Caribou NF, and western Elk Hills. Under future scenario 2, most of this peripheral area is lost, resulting in a distribution similar to that under the high mortality assumptions. Under the most optimistic assumptions (scenario 3 and low mortality), the ring of habitat facing greatest loss in occupancy is located further from the core GYE than in more pessimistic predictions, except in the northwest GYE. Nevertheless, under a range of plausible assumptions about grizzly bear habitat relations, continued human population growth coupled with road construction on public lands will eliminate many non-core areas of the GYE as potential habitat.

Wolf

The dynamic model results for the wolf show similarities to those from the low mortality grizzly bear simulations described above. Because the wolf can inhabit semi-developed habitat outside the core GYE, it is more dramatically impacted by future development in those areas. Potential demographic population structure under current conditions (Fig. 18a) shows source areas encompassing public lands in the central GYE as well as some adjacent private lands (e.g., Green

River valley, Dubois area, Elk Hills, Madison River valley). Wolf distribution is more biased towards the northwestern GYE (e.g., the Gravellies and Centennials) than is bear distribution. Connectivity exists between the GYE and central Idaho, the NCDE, and areas to the south (e.g., the Uintas). It is not unlikely, given their dispersal capacity, that wolves will soon colonize suitable areas of the UWRM outside of their present GYE distribution.

Under future scenario 2, outlying areas become sink habitats, and although connectivity is maintained to central Idaho, the GYE becomes isolated from more distant populations in the NCDE and Uintas (Fig. 18b). If road development is limited on public lands (scenario 3) , the viability of outlying populations (e.g., Wyoming Range, Bighorns) and connectivity to central Idaho is enhanced. This is more evident in comparing Figure 19a (current versus scenario 2) and Figure 19b (current versus scenario 3). It is notable that private lands areas between Dillon and Livingston and in the upper Green River valley that lose wolves under scenario 2 are likely to retain them if adjacent public lands are not degraded.

Wolverine

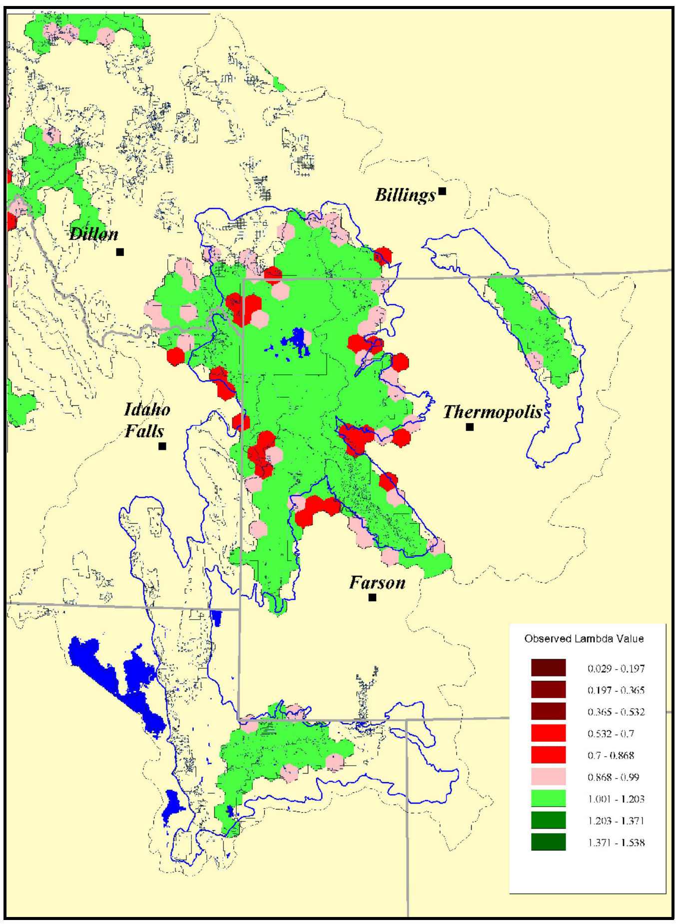


Figure 20. Distribution and demographic potential for wolverine in the UWRM region under current landscape conditions as predicted by the PATCH model.

The dynamic model results for the wolverine show a pattern of source and sink habitat familiar from results for the previous two large carnivore species. A ring of sink habitat surrounds the core source habitat of the park and adjacent public lands (Fig. 20). The existence of a large core protected area in the GYE helps buffer the local populations from extinction threats. Nevertheless, the small area occupied by the GYE population compared to that in central Idaho creates edge effects that lower the demographic potential of territories on the periphery of occupied habitat.

In southern British Columbia, wolverines may currently remain in many areas of currently degraded habitat due to proximity to more northerly source areas. This factors are not available to enhance the more isolated populations in the GYE or potential populations in the Uintas and Bighorns.

Lynx

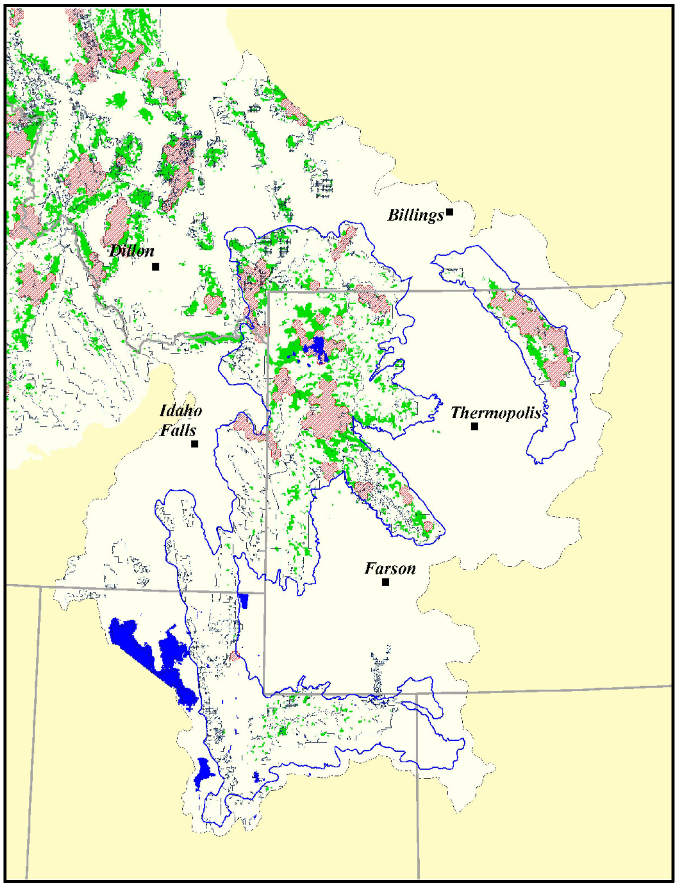


Figure 21. Comparison between areas with highest 20% predicted habitat suitability (RSF model) shown in green and areas occupied by lynx in the PATCH simulations outlined in red.

As a consequence of the more fragmented distribution and lower productivity of lynx habitat in the UWRM when compared with boreal regions (Fig. 14), PATCH simulations, although using a demographic cycle with an amplitude greatly reduced from that documented in boreal habitats, showed a high probability of local extinction within 200 years. Whereas the boreal zone is occupied fairly consistently due to its high habitat value—and the most southerly areas are vacant for the opposite reason—areas in between along the southern periphery of the range, such as the GYE, are occupied because of a complex combination of their site habitat value and their proximity to sources of dispersers.

A comparison of expected lynx habitat suitability with lynx distribution in the PATCH results (Fig. 21) suggests that only a small portion of the habitat that could theoretically function as a population source is actually occupied. This is because if a lynx population is extirpated during a cyclic low, an insufficient number of dispersers are available from regional source habitats alone to ensure that the area will be recolonized during a cyclic increase. Hence, the observed lynx distribution is aggregated along the U.S./Canada border to a greater degree than expected by the distribution of suitable habitat alone. Peripheral areas such as the GYE, and potentially the Uintas, have less occupied suitable habitat than expected. Lynx population dynamics are among the most complex shown by any carnivore, and these initial results are still tentative.

Evaluation of SITES Portfolios using the PATCH Model

The PATCH model was used in two ways to evaluate the effect of adding megasites to the current protected areas network:

1) Overlay of megasites on PATCH results. The irreplacability/vulnerability graphs based on the PATCH modeling (Figs. 22-24) show broad similarities with the graphs derived from the SITES modeling (see following section and Fig. 25). Nevertheless, consistent differences emerge due to the use of a dynamic spatial model that accounts for the landscape context of a site. For example, West Yellowstone is consistently among the most threatened of the sites. This is not because it faces the highest level of threat, e.g. in development pressure, but because its critical location adjacent to large source populations makes habitat degradation there a major demographic threat to regional carnivore populations. Only those megasites with greater than 50% probability of occupancy are shown in Figures 22-24.

2) Dynamic assessment of megasites. Megasites with both high SITES irreplaceability and high general vulnerability (as rated in the non-PATCH analysis) were assumed in this comparison to have no future increase in development after they were added to the portfolio. Protecting some megasites (for example, Henry's Fork) has a strong effect on focal species distributions, while protecting other areas has no effect. Sites whose protection has the greatest effect are generally those that fall in the upper right portions of the PATCH-based irreplaceability/vulnerability graphs. Protection of some smaller megasites (e.g., Upper Shoshone) has a "ripple effect" far beyond their immediate boundaries. This is more apparent for the wolf than for the grizzly bear because of the wolf's greater ability to inhabit semi-developed landscapes through dispersal from core protected areas.

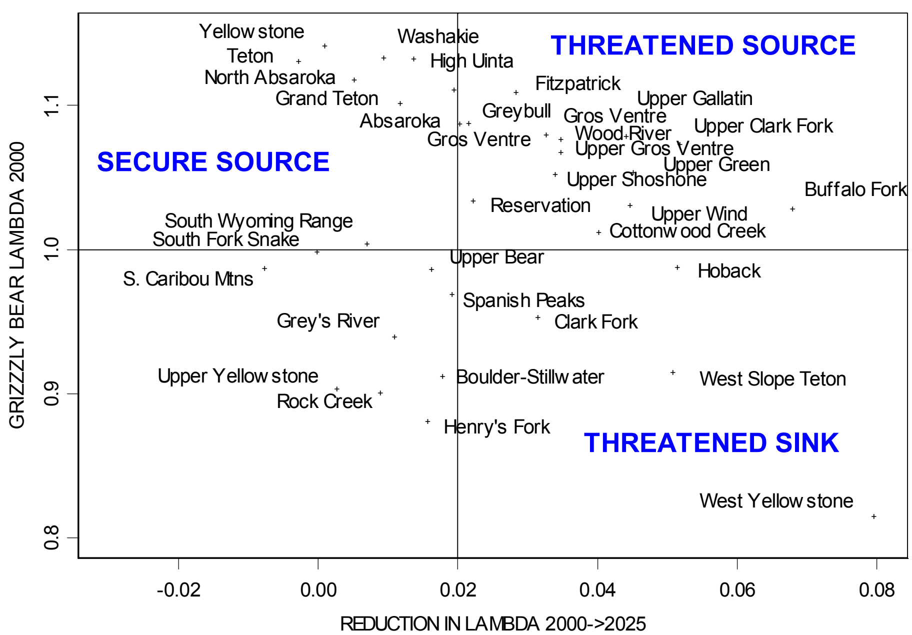


Figure 22. Irreplaceability versus vulnerability for megasites and protected areas based on the PATCH model for grizzly bear (high mortality parameters).

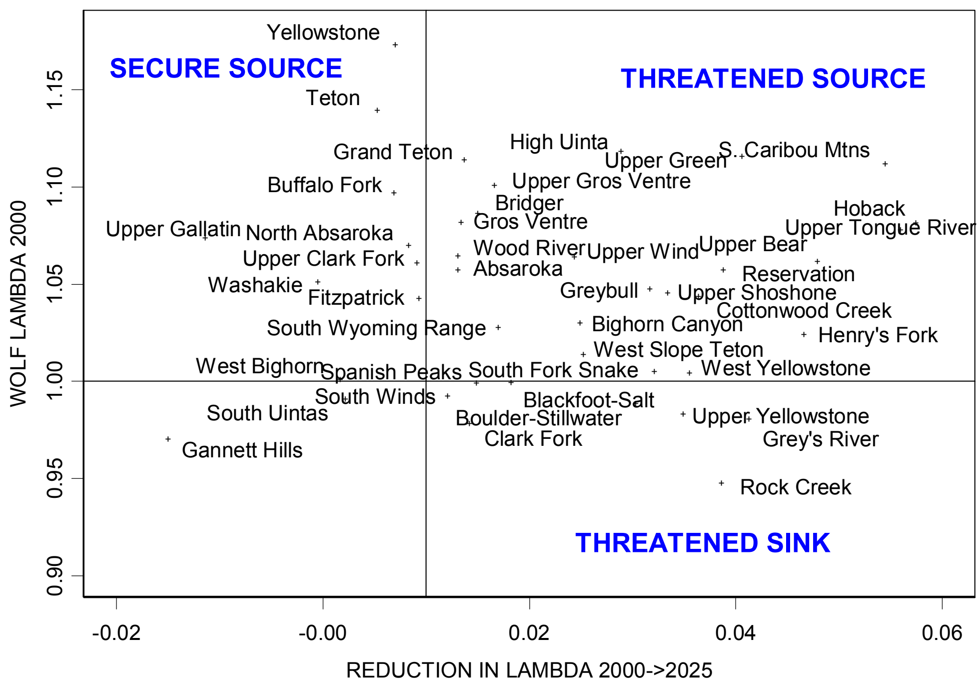


Figure 23. Irreplaceability versus vulnerability for megasites and protected areas based on the PATCH model for the wolf.

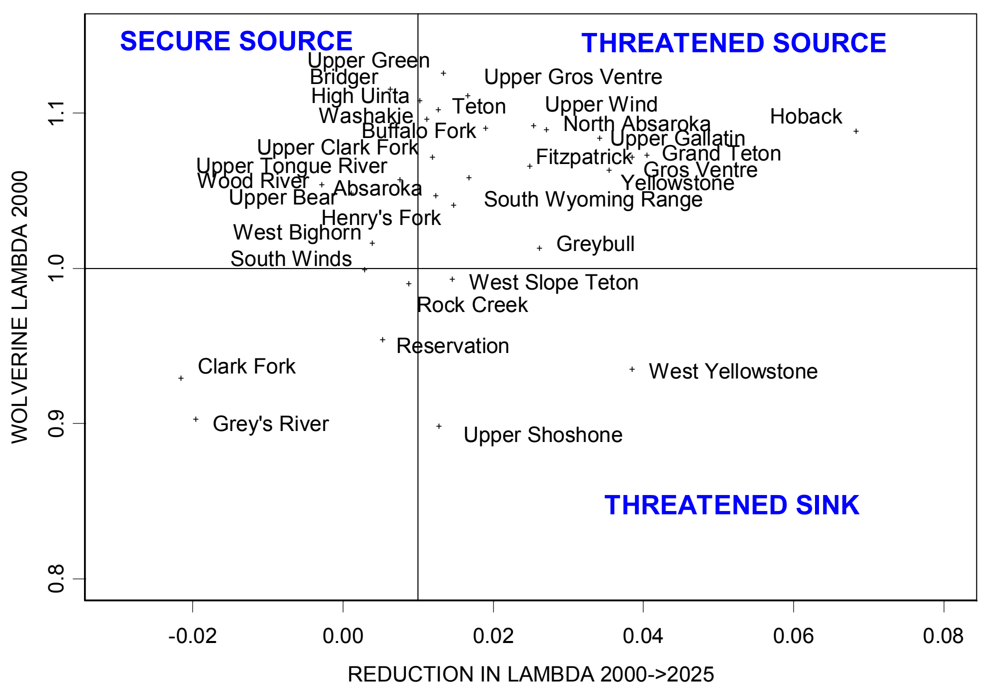


Figure 24. Irreplaceability versus vulnerability for megasites and protected areas based on the PATCH model for the wolverine.

Irreplaceability versus Vulnerability

Megasite irreplaceability scores ranged from 7.5 to 94.4 (mean: 49.7), and vulnerability scores from 1.5 to 98.5 (mean: 52.2). Our irreplaceability vs. vulnerability prioritization resulted in 9 megasites totaling 2.2 million acres in the high irreplaceability-high vulnerability quadrant 1, giving them the highest priority for conservation action (Figs. 25, 26). Twelve megasites in quadrant 2 (high irreplaceability-low vulnerability, medium priority) cover 2.8 million acres; 13 megasites in quadrant 3 (low irreplaceability-high vulnerability, medium priority) cover 4.4 million acres; and 9 megasites in quadrant 4 (low irreplaceability-low vulnerability, lower priority) cover 0.8 million acres.

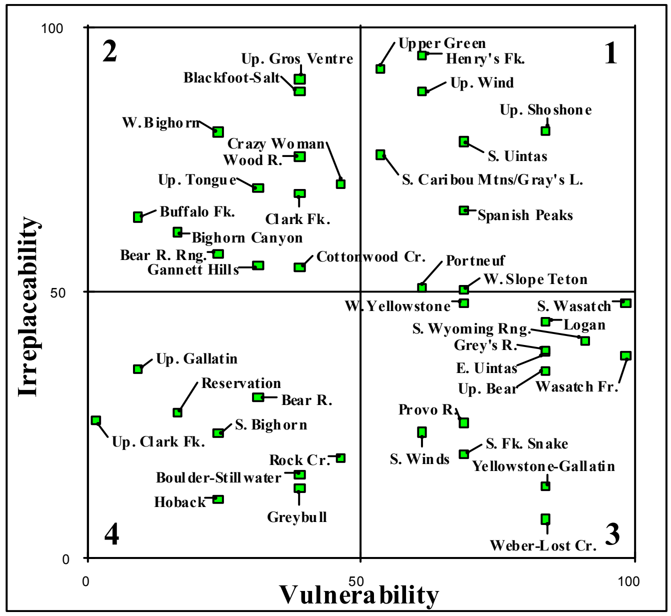


Figure 25. Megasite irreplaceability and vulnerability, with quadrants.

To rank megasites in terms of conservation priority, we first grouped them into quadrants (following Margules and Pressey 2000), then ordered them within quadrants according to their combined irreplaceability and vulnerability scores (Table 2). We differ from Margules and Pressey (2000) in giving slightly higher weight to the upper left quadrant (our quadrant 2, their quadrant 3) over the lower right quadrant, because we feel that sites of very high and irreplaceable biological value merit conservation action even if not highly threatened today. That is, it is a good idea to protect these sites while they are still reasonably intact. In the UWRM, at least, the private lands in these areas are generally less expensive to protect than more threatened sites, because they are usually in areas with lower population growth and development pressure.

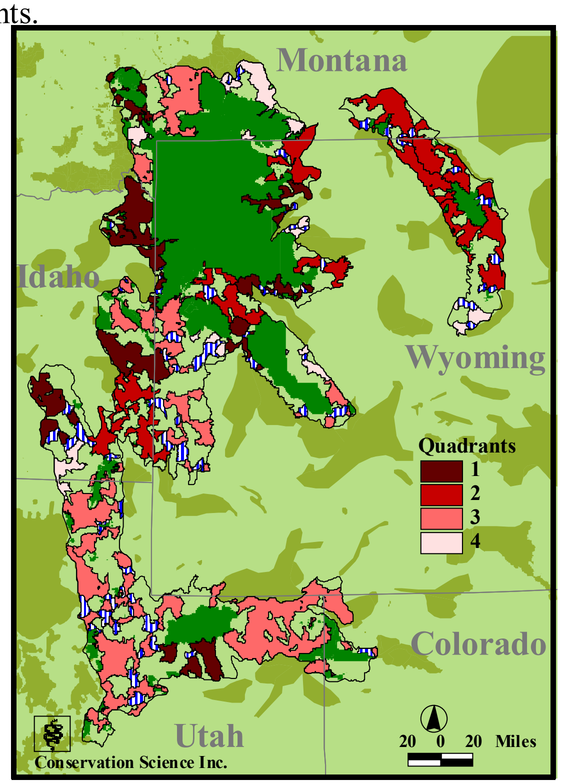


Figure 26. Megasite quadrants, connectivity zones hatched blue.

Table 2. Megasites of the UWRM. Sites within each quadrant are ordered by their combined irreplaceability and vulnerability scores.

Rank	Name	Irreplaceability	Vulnerability	Irreplaceability + Vulnerability	Quadrant	Acres
1	Upper Shoshone	80.5	83.6	164.1	1	170388
2	Henry's Fork	94.4	61.2	155.6	1	450148
3	Upper Wind	87.7	61.2	148.9	1	167651
4	South Uintas	78.4	68.7	147.1	1	272142
5	Upper Green	92.1	53.7	145.8	1	127044
6	Spanish Peaks Additions	65.4	68.7	134.1	1	129715
7	S. Caribou Mtns/Gray's Lake	75.8	53.7	129.5	1	392377
8	West Slope Teton	50.3	68.7	119.0	1	148776
9	Portneuf	50.8	61.2	112.0	1	317620
10	Upper Gros Ventre	90.1	38.8	128.9	2	214156
11	Blackfoot-Salt	87.8	38.8	126.6	2	207700
12	Crazy Woman	70.6	46.3	116.9	2	328075
13	Wood River	75.5	38.8	114.3	2	59149
14	Clark Fork	68.6	38.8	107.4	2	298774
15	West Bighorn	80.1	23.9	104.0	2	182284
16	Upper Tongue	69.8	31.3	101.1	2	332385
17	Cottonwood Creek	54.6	38.8	93.4	2	98597
18	Gannett Hills	55.1	31.3	86.4	2	219983
19	Bear River Range	57.2	23.9	81.1	2	182908
20	Bighorn Canyon	61.4	16.4	77.8	2	560287
21	Buffalo Fork	64.0	9.0	73.0	2	76479
22	South Wasatch	48.1	98.5	146.6	3	255852
23	Wasatch Front	38.2	98.5	136.7	3	255344
24	South Wyoming Range	40.9	91.0	131.9	3	301036
25	Logan	44.6	83.6	128.2	3	477824
26	Grey's River	39.3	83.6	122.9	3	271987
27	East Uintas	38.8	83.6	122.4	3	1225041
28	Upper Bear	35.2	83.6	118.8	3	113000
29	West Yellowstone	48.0	68.7	116.7	3	108986
30	Up. Yellowstone-Up. E. Gallatin	13.6	83.6	97.2	3	486501
31	Provo River	25.5	68.7	94.2	3	348631
32	Weber-Lost Creek	7.5	83.6	91.1	3	202483
33	South Fork Snake	19.6	68.7	88.3	3	222651
34	South Winds	23.7	61.2	84.9	3	107554
35	Rock Creek	18.9	46.3	65.2	4	47861
36	Bear River	30.3	31.3	61.6	4	156986
37	Boulder-Stillwater	15.8	38.8	54.6	4	240212
38	Greybull	13.3	38.8	52.1	4	48022
39	South Bighorns	23.5	23.9	47.4	4	99998
40	Upper Gallatin	35.7	9.0	44.7	4	69249
41	Reservation	27.6	16.4	44.0	4	71440
42	Hoback	11.3	23.9	35.2	4	60219
43	Upper Clark Fork	25.9	1.5	27.4	4	18332

Some megasites have higher combined scores than others that fell into higher-priority quadrants—for example, the top 4 megasites in quadrant 2 have higher combined scores than the lowest-ranked megasite in quadrant 1. Such discrepancies are an inevitable consequence of arbitrarily dividing a binary continuum into quadrants. Nevertheless, the conceptual simplicity of the quadrant graph aids decision-making. For instance, different areas of the graph (Fig. 25) may indicate the need for different types of protection and management prescriptions (Margules and Pressey 2000). In practice, site-specific factors considered in planning exercises more detailed and fine-scale than the regional assessment described here will be required to evaluate the relative values of different areas that may be scored in close proximity by our method.

Progress toward conservation goals can be achieved most efficiently by protecting first the highest priority megasites (quadrant 1), then the medium priority megasites (quadrants 2 and 3), and finally the lower priority megasites (quadrant 4), as shown in Figure 27 and Table 3. The greatest incremental gains are achieved by protecting the 9 megasites in quadrant 1, resulting in an average increase of over 14% for the three tracks (42.9% currently to 56.3%). Protecting the 12 megasites from quadrant 2 increases average protection for the three tracks another 11%, to 67%. Protecting the 13 megasites in quadrant 3 increases average protection to 84.7%, and protecting the 9 megasites in quadrant 4 results in 85.9% average protection for the three tracks.

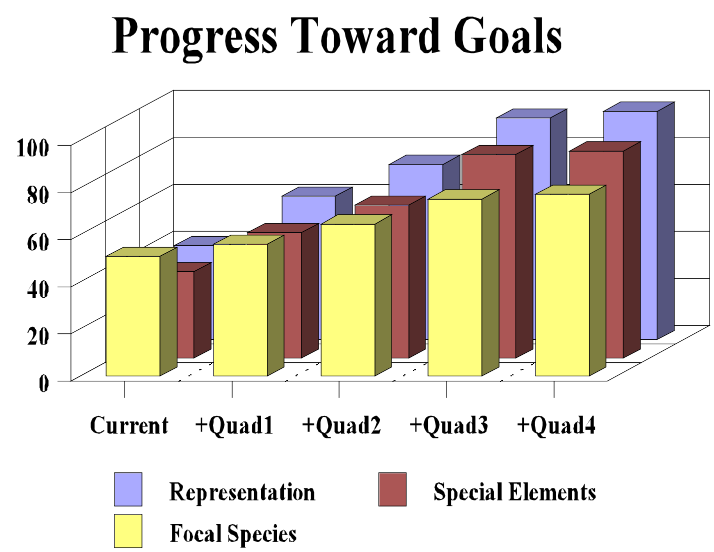


Figure 27. Increases in achieving conservation goals by incrementally protecting megasites in the four quadrants of the irreplaceability vs. vulnerability graph (Fig. 25)

As shown in the "Δ" column in Table 3, the proposed portfolio—if fully protected—would cover 37% more of the ecoregion than the current reserve network. For that 37% increment, there is a considerable "bang for the buck" for many elements—for example, a 58% increase (to 100%) in coverage of G1/G2 species, a 51% increase for all special elements combined, and a 57% increase for representation of ecological systems (vegetation, aquatic habitats, and vegetation and physical habitats combined).

Table 3. UWRM portfolio conservation target protection increases.

	Current %	Plus Quad1	Plus Quad2	Plus Quad3	Plus Quad4	Total Δ (%)
Protected Area	30.0	38.1	48.5	64.5	67.5	+37.5
Special Elements						
All G1-G2	41.8	51.7	60.3	98.8	100	+58.2
Class 1–Local-Scale Species	42.7	51.7	65.8	89.0	91.3	+48.6
Class 2–Birds	30.1	61.5	70.7	85.9	86.5	+56.4
Class 4–Fish	26.7	29.2	35.4	60.9	61.7	+35.0
Class 5–Plant Communities	41.7	73.0	92.5	97.4	100	+58.3
Special Elements Average	36.6	53.2	64.9	86.4	87.9	+51.3
Focal Species Resources						
Elk Winter Range	14.0	22.4	36.5	57.4	61.7	+47.7
Grizzly	91.6	92.5	94.4	96.8	97.3	+5.7
Lynx	36.9	45.0	56.5	67.8	70.5	+33.4
Wolf	71.9	74.4	79.9	86.0	87.1	+15.2
Wolverine	40.1	46.9	56.0	68.5	70.6	+30.5
Focal Species Average	50.9	56.2	64.7	75.3	77.4	+26.5
Representation						
≥ 25-35%–Vegetation Types	38.6	68.2	72.3	100	100	+61.4
≥ 10%–Vegetation/Physical Habitat Types	44.7	58.5	71.9	89.2	93.9	+49.2
≥ 35%–Aquatic Types	36.5	56.3	79.0	93.3	96.7	+60.2
Representation Average	39.9	61.0	74.4	94.2	96.9	+57.0
Total Average	42.9	56.3	67.0	84.7	85.9	+43.0

DISCUSSION

Because biological conservation relies almost entirely on *in situ* protection, conservation is ultimately a matter of making decisions about land-use and land-management. As noted by Australian biologist Bob Pressey (1998):

> The science of conservation planning aims to put the right conservation measures, as far as possible, in the right places. A conservation measure is right if it provides enough protection from threatening processes to maintain the natural features of concern. A place is right if it has priority for conservation action to promote the persistence of features that would otherwise disappear.

The three tracks of conservation planning pursued in this study are designed to provide a comprehensive assessment of conservation opportunities in the UWRM, given available information. The results, we hope, will provide a basis for a variety of land protection and management activities, including reserve design and acquisition, conservation easements, management agreements and stewardship assistance to landowners, agency designations of special management areas (e.g., research natural areas [RNAs], areas of critical environmental concern [ACECs], botanical areas), congressional actions such as wilderness designations, and such administrative actions as national monument designations. Land trusts, conservation groups, government at all levels, industry, and community groups are among the potential users of information on the relative conservation value of different areas. Because this approach to conservation planning is based on defensible scientific data, principles, and methods, it minimizes potential socioeconomic and ideological biases. It also clarifies the consequences of land-use decisions. When the trade-offs involved in such choices are explicit and transparent, conflicts between competing values can be minimized. Ultimately, it is in the best interests of everyone—from environmentalists to industry—to minimize conflicts.

Although it must take every measure possible to be scientifically rigorous and free of bias, conservation planning is not value-free. The generally accepted goals of conservation planning (representing ecosystems, maintaining viable populations of native species, etc.) are based on the value assumption that biodiversity is good and ought to be preserved. Given this assumption, and agreement on the goals that derive from it, conservation planners have an obligation to pursue answers to key questions and solutions to problems as objectively as possible. This “science-based” approach to conservation planning has several key features, which together serve as standards on which to judge the defensibility of a plan (Noss 1999):

- Scientists are intimately involved throughout the process, from the initial formulation of goals and hypotheses to the completion of the plan and, in some cases, its implementation.

- Goals, objectives, hypotheses, and research questions are all made explicit from the start. Nothing is hidden.

- The methodology is rigorous and systematic, within the constraints imposed by large-scale planning, and it seeks to answer the stated questions.

- The methodology is well documented and replicable. The studies could be repeated by others.

- Data analysis is as rigorous and objective as possible, with the assumptions and limitations of the approach clearly acknowledged.

- The interpretation and application of results are congruent with principles (i.e., empirical generalizations) of conservation biology and demonstrate a good command of the relevant literature and theory.

- The data, models, and analyses are available to the public. (Lack of access to this information precludes full peer review and other critiques.)

- The project is thoroughly peer-reviewed by scientists who are independent (not financially or emotionally connected to the project) and competent in the relevant subject areas. Peer review comments are thoughtfully considered and responded to (i.e., either each of the reviewers' suggestions is followed or an adequate reason is given for not following it).

- At least some of the results are publishable in reputable, peer-reviewed journals.

- The entire process, from developing research methods through implementation, is iterative and adaptive. There is no "final plan," rather the plan is continually refined and improved with feedback from research, monitoring, peer review, and learning by doing.

Special Elements and Representation

Although the UWRM is not considered a biological hotspot at a global or continental scale (Ricketts et al. 1999, Myers et al. 2000), it presents an opportunity that most of the hotspots, which are largely in tropical, subtropical, and Mediterranean climates, do not—to conserve a full suite of native species within a reasonably intact ecosystem. The GYE, in particular, is widely recognized as the most southerly intact ecosystem in North America. One must go northward into the Canadian Rockies or boreal and tundra zones to find areas in equally good condition with complete native faunas. Hence, representing all native species and ecosystems—including the very rarest (i.e., special elements)—is as high a priority in the GYE and UWRM as in more southerly areas with higher species richness and endemism.

Special elements and ecological systems (vegetation, geoclimatic habitats, and aquatic habitats) in the UWRM would be much more secure if our proposed portfolio of megasites were added to the current network of protected areas. All (100%) of the most highly imperiled (G1/G2) species and communities would be captured, a 58% increase over the current system. Similarly, 96.9% of ecological systems representation goals would be met, a 57% increase over the current condition. This considerable "bang for the buck" would be achieved with a 37% increase in protected area.

We are reasonably confident that the three classes of ecological systems represented by our portfolio provide a functional coarse filter, although the coarse filter hypothesis could not be truly tested without a complete inventory of the entire biota of the region. Much more uncertainty is associated with protection of special elements. Although the UWRM, and especially the GYE, because of its popularity with naturalists, probably has been better surveyed than most regions of the American West, strong biases in heritage program databases undoubtedly exist. For instance, some portions of the UWRM are quite poorly known biologically, such that absence of element occurrences from these areas probably reflects an absence of surveys more than the absence of imperiled species and communities. Unfortunately, the heritage program databases do not allow these two classes of absence to be discriminated. With more complete field surveys some of our megasites with low scores for irreplaceability might surpass other, better surveyed megasites and move into higher-priority quadrants. Nevertheless, our combination of the three tracks of special elements protection, representation of ecological systems, and protection of focal species' habitat was designed explicitly to be complementary, such that the deficiencies in any one track are compensated by other tracks. This complementarity minimizes the effects of biases related to missing or inaccurate data. Therefore, we predict that our overall priority ranking of megasites would change relatively little with more complete data.

Focal Species

Our treatment of focal species in this assessment differs from conventional approaches in the Rocky Mountains and elsewhere. Typically, conservation planning and reserve design for charismatic species such as grizzly bears involves expert judgments about potential core areas and subjective delineation of linear linkages to provide connectivity. We have taken a more analytic approach by using both static and dynamic models to assess the roles of potential core and linkage areas. By linking demography to mapped habitat characteristics, the dynamic models have revealed how particular areas may influence the overall viability of the region's carnivore species under current and future conditions. An understanding of the regional mechanisms driving population viability is a necessary foundation for conservation action, because without an accurate understanding of the regional context we cannot evaluate the relative demographic effect of a potential core or corridor, or how likely animals are to use these areas.

Although they are not directly linked to species demography, the static models contributed greatly to our understanding of regional conservation needs. For species such as the lynx and wolverine, whose habitat associations are poorly known, the static habitat suitability modeling takes full advantage of the meager data on species distribution to produce input maps that strengthen the realism of the subsequent dynamic modeling. For better-known species such as the grizzly bear and wolf, the static models provided many new insights on seasonal and temporal trends in habitat use and the influence of differences in land management on species distribution.

A primary lesson from our focal species analysis is how challenging it will be to conserve and restore carnivores in the UWRM. Many of the carnivore populations in the region are on the periphery of their range due to climatic or historical factors, or both. For both reasons these peripheral populations are at a disadvantage in that they cannot expect a large demographic "rescue effect" from surrounding regions. Nevertheless, conservation actions to enhance population viability may differ depending on whether historical or climatic limits predominate. Species with more boreal habitat associations such as the lynx and wolverine experience the GYE and other boreal habitats of the UWRM as islands of forest habitat surrounded by low elevation non-forested areas. Their continued presence in the region is also likely due to the refugium from trapping provided by Yellowstone National Park and, to a lesser extent, other protected areas (Buskirk et al. 1999; see also our dynamic modeling results).

Distribution of the grizzly bear and wolf, in contrast, historically extended into Mexico. The GYE forms the southern periphery of current distribution due to the north-to-south gradient of increasing human impacts on the continent and Yellowstone's status as a National Park. (In the case of the wolf, the park's status did not prevent extirpation but provided an obvious location for a restoration program.) The ability of protected areas to serve as refugia depends on a combination of area, lack of isolation, and habitat quality. As noted earlier, because of potential conflicts with human economic uses, parks tend to be located in areas of low biological productivity (Noss and Cooperrider 1994, Scott et al. 2001). In comparison to the Canadian mountain parks, however, Yellowstone NP and its surroundings boast relatively high productivity, which has helped this region retain a full complement of native species even though relatively isolated.

Potential Future Trends in Carnivore Populations

Two factors reduce the ability of our proposed portfolio to assure long-term persistence of carnivores: 1) Because populations are centered on protected areas, population viability of large carnivores depends to a large extent on changes in management within those areas (e.g., reduction in mortality related to hunting, conflicts with livestock grazing, and roadkill). And, 2) Factors causing declines in carnivore populations (e.g., human population growth) have a strong regional and inter-regional component. Hence, strategies to mitigate these factors must focus both on reserves and on improved management of multiple-use matrix lands within and beyond the UWRM.

The UWRM is experiencing high human population growth in several portions of the region, accompanied by increased development, road-building, traffic on highways, and other threats to biodiversity. In this study we analyzed the potential effects of alternative future scenarios primarily in terms of their effects on our selected focal species. Human population growth and resulting landscape change have strong effects on carnivore viability in the region, effects that may not be obvious from data on the current status of the species. Human land uses such as grazing and organized predator control, which have been characteristic of the region since European settlement, are less extensive or less lethal to predators today than a century ago. This has allowed the local populations of grizzly bear and wolves to expand in distribution into areas that lack

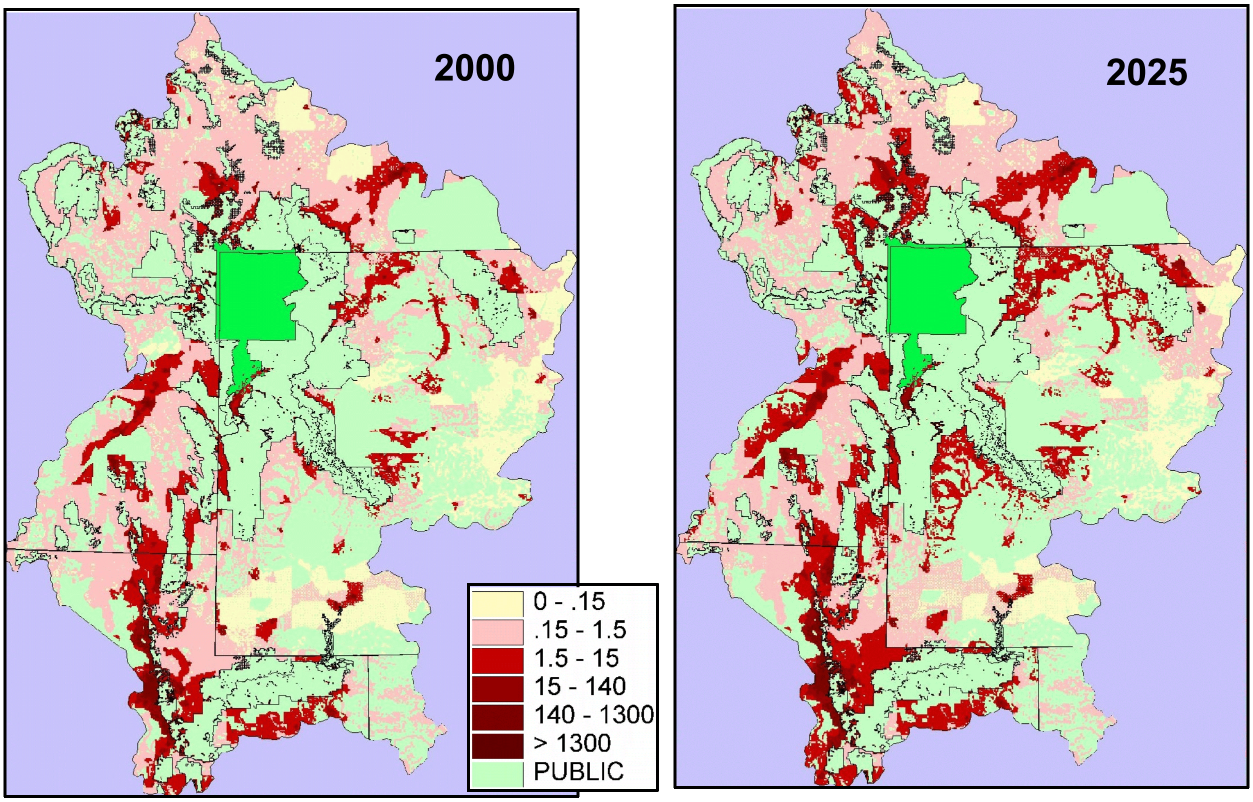


Figure 28. Current and predicted housing density per square kilometer (data from Theobald 2001)

species that they could support under current conditions. As these carnivore populations rebound from historical eradication efforts, however, they will find their habitat options increasingly foreclosed by the rate of landscape change.

The UWRM is unique in the western United States in that large core refugia lie in close proximity to rapidly growing human populations (Fig. 28). Currently, the core refugia of parks and wilderness areas in the GYE can support carnivore populations in the extremities of the ecoregion. Because these outlying areas may not yet be occupied by expanding carnivore populations, they may not receive adequate conservation focus and may be more subject to competing land uses such as grazing (Fig. 29) than are areas within the core ecosystem. If current trends continue, a ring of development will increasingly surround the core with sink habitat, isolating it from the "arms and legs" of the ecoregion and weakening its ability to sustain carnivores in those outlying areas.

The structure of regional metapopulations suggested by the PATCH models implies that conservation priorities will differ among species. For the lynx, our results suggest that proportionately small changes in habitat area and connectivity may result in threshold effects with major consequences for species viability. Whether this is a hopeful or cautionary message depends on the efficacy of conservation efforts, but it underscores the necessity of coordinating planning for these wide-ranging species across many jurisdictions and ownerships. Protecting and enhancing habitat in the UWRM should be coupled with protection of likely regional source populations in the transborder region.

The GYE grizzly bear population appears to be demographically isolated under most plausible landscape scenarios. While this may pose long-term dangers from genetic isolation, the PATCH model results suggest relatively high probabilities of persistence for this isolated population over the short- to medium-term. Nevertheless, the results also suggest a dramatic impact of future landscape change on potential distribution and size of the region's bear population. The first priority should be given to protecting these at-risk areas. The increase in predicted distribution caused by changes in roadless area management policy, as initiated under the Clinton administration, are encouraging; we only hope this protection persists and strengthens. An increased public lands grizzly bear recovery zone, when coupled with conservation strategies on private lands identified as critical population sinks, could potentially double the area occupied by grizzly bears in the GYE, with a resulting increase in population viability.

Whereas ideally conservation sites could enhance both inter-regional connectivity and regional population viability, in reality the two goals suggest somewhat differing priority areas. The eastern and southern GYE (Shoshone and Bridger-Teton NFs and western Bighorn Basin) show the most potential for augmenting bear distribution and numbers. Other areas such as the Gravellies and Centennials, which could arguably enhance interregional connectivity, have a somewhat lower, though still important, impact on regional viability. A major conclusion for the grizzly bear, as well as the wolverine and lynx, is the high potential of the Wyoming Range, Caribou NF, and adjacent areas to provide available carnivore habitat under optimistic scenarios. Conversely, because these areas are peninsular extensions from core GYE refugia, they are extremely vulnerability to species loss if current trends continue. This peninsular vulnerability is shared by the Gravellies and Centennial Mountains.

The wolverine may soon receive comparable attention as the lynx, with probable legal recognition of its threatened status in the contiguous United States. The GYE wolverine population, like that of the grizzly bear, appears viable over the next century under current conditions. It should benefit from some of the habitat protection and management actions, such as road removal, adopted for the grizzly bear. Other threats such as incidental trapping and poisoning should be assessed as part of a comprehensive conservation strategy that ideally would be coordinated with management in southern Canada. Because of their high vagility, wolverine in Idaho and the GYE likely form part of a regional population which influences their overall viability in a manner not evident in the grizzly bear.

Metapopulation concerns assume a higher priority in the case of wolf. Current landscape conditions should allow the species to form a connected metapopulation encompassing most public lands and some adjacent private lands in the GYE and some other portions of the ecoregion (i.e., the Bighorns, Uintas, and the southern Wasatch). Despite some setbacks, the high rate of population increase in the 6 years since reintroduction to the GYE support this prediction, as does wolf recovery in the northcentral U.S. The GYE arguably has more productive wolf habitat than that occupied by more precarious populations in the Northern Continental Divide Ecosystem and

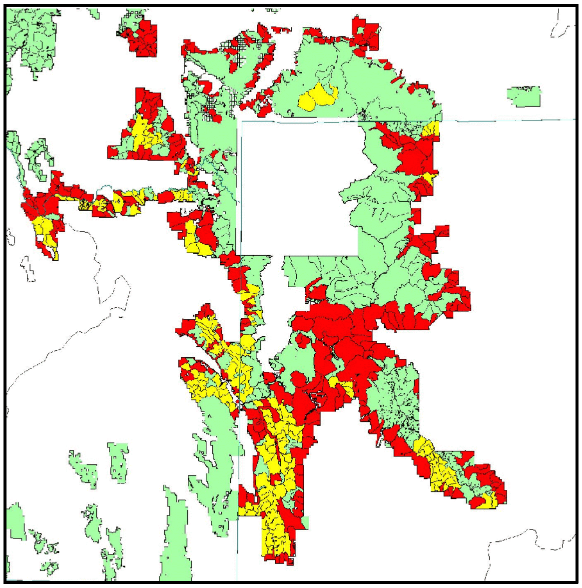


Figure 29. Active grazing allotments on Forest Service lands within the GYE. Cattle allotments are shown in orange and sheep allotments in yellow. Green indicates no grazing, or no data when outside the GYE.

Banff region (Carroll et al. 2001b). Although under current conditions wolves can thus be managed as a single northern Rocky Mountain metapopulation, future landscape change threatens to partially isolate wolves in the GYE/UWRM from adjacent regions, and perhaps more importantly, alienate much of the productive lower elevation habitat that could currently support wolves. Because demographic rescue from core areas would be important in sustaining wolves in matrix habitat, high priority should be given to maintaining habitat continuity between the GYE central Idaho populations. Because these two populations would optimistically serve as sources for colonization of more southerly areas such as the Uintas, a secondary priority would be to maintain connections to the south. Given the species' high vagility, dispersal between these areas and proposed reintroduction areas in central Colorado may be possible.

Given the contrasts between species, building a conservation strategy that combines priority areas for the entire carnivore guild is challenging. Areas of high value for multiple species must combine both biological productivity and security from human impacts (Carroll et al. 2001a). Such areas (e.g., undeveloped riparian areas) are scarce in the UWRM and tend to be highly threatened by development (Hansen and Rotella 1999). Comparison of the results from our alternate future scenarios suggests that only about half of the loss in carnivore carrying capacity is linked to development on public lands. Even for wide-ranging species such as the grizzly bear that are closely associated with wilderness, conservation planning limited to public lands is not sufficient.

Conclusions

In the real world, protection opportunities will not arise in an orderly sequence that corresponds to science-based priorities. For example, megasites in quadrants 2 or 3 may become available for protection before megasites in quadrant 1; if not protected quickly, some of these sites may be converted to subdivisions. Yet funds, or political capital, spent protecting these sites may preclude opportunities for protecting biologically more significant sites in the future. What is the optimal course of action under such circumstances?

We suggest that conservationists implement an informed opportunism, taking advantage of many conservation openings as they arise, but with explicit recognition of the trade-offs involved. Sometimes it will be better to act and other times to wait. Systematic conservation planning allows the effects of trade-offs to be quantified and considered in a biologically meaningful way.

With information made transparent and explicit, decision-makers will be able to take actions which, we hope, are scientifically defensible and result in the most biodiversity conserved.

As a regional-scale assessment, our study does not provide all that is needed to implement conservation action on the ground. For example, none of our megasites is irreplaceable for all nine of the conservation criteria used to score and prioritize areas. As large areas, the megasites are internally variable in conservation value, so100% irreplaceability for even a single criterion applies correctly not to the entire megasite, but usually to only a small portion of the site. Some of these smaller sites are truly irreplaceable. Beyond our regional-scale study, detailed site-level assessments are needed to identify the planning units and individual patches of habitat that are completely irreplaceable for one or more criteria. Conservation planning is an iterative exercise, and each iteration should provide more accurate and higher-resolution information. We hope our study has provided the scientific foundation upon which defensible site-level planning and implementation will be based.

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APPENDICES

Appendix A: TARGETS AND GOALS

Class 1: Species with restricted distributions globally (G1/G2) or which are endemic to or disjunct in the ecoregion, declining, highly vulnerable, or otherwise of high conservation interest. These are "local-scale" species and can be addressed through a traditional TNC fine-filter approach focused on relatively small sites or portfolios of such sites.

Goal: Protect 100% of viable occurrences of G1/G2 species and at least 10 viable occurrences of all others.

Plant Species

Species Name	Common Name	G/S Rank[1]	ESA/Sens	States[2]
Abronia ammophila	Yellowstone sand verbena	G1,S1		WY
Adiantum aleuticum	Aleutian maidenhair fern	G5?,S1		WY
Adiantum capillus-veneris	southern maiden-hair	G5,S2	FS	CO
Adoxa moschatellina	Moschatel/musk root	G5,S1		MT,WY
Agoseris lackschewitzii	pink agoseris	G4,S2S3	FS/BLM	ID,MT,WY
Agrostis rossiae	Ross bentgrass	G1,S1		WY
Amerorchis rotundifolia	round-leaved orchid	G5,S1		WY
Anemone narcissiflora ssp *zephyra*	zephyr windflower	G5T4,S1		WY
Antennaria aromatica	aromatic pussytoes	G4,S2S3		WY
Antennaria flagellaris	stoloniferous pussytoes	G5?,S1		WY
Antennaria monocephala	single-head pussytoes	G4G5,S1		WY
Anticlea vaginatus	alcove death camas	G2,S2		CO
Aquilegia grahamii	Grahams columbine	G1,S1		UT
Aquilegia formosa	sitka columbine	G5,S1		MT
Arabis lasiocarpa	Wasatch rockcress	G3,S3		UT
Arabis pendulina var. *russeola*	daggett rock cress	G5T3?,S3		WY
Arabis vivariensis	park rock cress	G2G3Q,S1		UT
Arctostaphylos rubra	red manzanita	G5,S1	FS	WY
Arctostaphylos rubra	red manzanita	G5,S1	FS	WY
Arnica lonchophylla	northern arnica	G4,S2	FS	WY
Artemisia campestris var *petiolata*	petiolate wormwood	G5T1?,S1?		UT
Artemisia norvegica var *piceetorum*	spruce wormwood	G5T1Q,S1		UT
Asclepias hallii	Hall milkweed	G3,S1		UT
Asplenium trichomanes-ramosum	green spleenwort	G4,S2		WY
Asplenium viride	green spleenwort	G4,S1	FS	ID,UT

[1]S-rank reflects range in ranking within a state (i.e., where there is uncertainty) as well as range in ranks among states.

[2]States where the element is found within ecoregion *and* in which it is considered of high conservation value.

Aster glaucodes	gray aster	G4G5,SU		MT
Aster junciformis	rush aster	G5,S1	FS	ID
Aster kingii var *barnebyana*	Barnebys rockaster	G3T1,S1		UT
Aster kingii var *kingii*	Kings aster	G3T3,S3		UT
Aster mollis	soft aster	G3,S3	FS	WY
Astragalus aretioides	sweetwater milkvetch	G4,S2		MT
Astragalus argophyllus var *martinii*	a milk-vetch	G5T4,S4		UT
Astragalus bisulcatus var *bisulcatus*	two-groove milkvetch	G5T5,S2		ID
Astragalus ceramicus var *apus*	painted milkvetch	G4T3,S1		MT
Astragalus chloodes	grass milkvetch	G3,S3		UT
Astragalus convallarius var *convallarius*	lesser rushy milkvetch	G5T5,S2		MT
Astragalus drabelliformis	big piney milkvetch	G2G3,S2S3	BLM	WY
Astragalus duchesnensis	duchesne milkvetch	G3,S1S2	BLM	CO
Astragalus gilviflorus	plains milkvetch	G5, S2		ID
Astragalus hamiltonii	Hamilton milkvetch	G1,S1		UT
Astragalus jejunus var. *jejunus*	starveling milkvetch	G3T3,S2	BLM	ID
Astragalus lonchocarpus var *hamiltonii*	Hamilton milkvetch	G1,S1		CO
Astragalus lutosus	dragon milkvetch	G4,S3		UT
Astragalus paysonii	Payson's milkvetch	G3,S2	FS	WY
Astragalus robbinsii	Robbins milkvetch	G5,S1		UT
Astragalus saurinus	dinosaur milkvetch	G3,S3		UT
Astragalus shultziorum	Schultz's milkvetch	G3Q,S3		WY
Astragalus terminalis	railhead milkvetch	G3,S1S2		WY
Balsamorhiza macrophylla	large-leafed balsamroot	G3G5,S1		MT
Boechera fernaldiana	park rockcress	G3G4T3T4,S2		CO
Bolophyta ligulata	ligulate feverfew	G3,S2	BLM	CO
Botrychium crenulatum	crenulate moonwort	G3,S1		WY
Botrychium crenulatum	dainty moonwort	G3,S1		UT
Braya glabella	Arctic braya	G5,S1		WY
Braya humilis	low braya	G5,S1		WY
Camissonia andina	obscure evening-primrose	G4,S1		MT
Carex buxbaumii	Buxbaum's sedge	G5,S3	FS/BLM	ID
Carex curatorum	canyonlands sedge	G2,S2		UT
Carex gravida var *gravida*	pregnant sedge	G5T?,S1		MT
Carex incurviformis	seaside sedge	G4G5,S2		WY
Carex leptalea	bristly-stalk sedge	G5, S1		UT
Carex livida	pale/livid sedge	G5,S1S2	FS/BLM	ID,WY
Carex luzulina var. *atropurpurea*	black and purple sedge	G5T3,S2	FS	WY
Carex microglochin	false uncinia sedge	G5?,S1		WY
Carex multicostata	many-ribbed sedge	G5,S1		MT
Carex nelsonii	Nelson's sedge	G3G4,S2		WY
Carex norvegica ssp *inserrulata*	toothed Scandinavian sedge	G5T?Q,S1		MT
Carex parryana ssp *idahoa*	Idaho sedge	G4T2,S2	BLM	ID, MT
Carex stenoptila	small-winged sedge	G3?,S2		MT
Carex tincta	slender sedge	G4G5,SU		MT
Castilleja crista-galli	cock's-comb paintbrush	G3?,S2		WY
Castilleja exilis	annual indian paintbrush	G5,S2		MT
Castilleja gracillima	slender indian paintbrush	G3G4,S2		MT
Castilleja nivea	snow paintbrush	G3,S2		WY

Cicuta bulbifera	bulb-bearing water-hemlock	G5,S1S2	FS/BLM	ID,WY
Cirsium eatonii var *murdockii*	Murdocks thistle	G5T2T3,S2S3		UT
Cirsium ownbeyi	Ownbey thistle	G3,S2	BLM	CO,UT
Claytonia lanceolata var *multiscapa*	yellow spring-beauty	G5T4,S1		ID
Cleomella palmeriana var *goodrichii*	Palmers cleomella	G3?T1,S1		UT
Corydalis caseana ssp *brachycarpa*	Wasatch fitweed	G5T2,S2		UT
Cryptantha breviflora	Uinta basin cryptantha	G4,S2		ID,UT
Cryptantha caespitosa	caespitose cats-eye	G4,S1?		UT
Cryptogramma stelleri	fragile rockbrake	G5,S1		WY
Cymopterus evertii	Everts waferparsnip	G2G3,S1		UT
Cymopterus lapidosus		G3,S1		UT
Cymopterus lapidosus	echo spring-parsley	G3,S2S3		WY
Cymopterus williamsii	Williams spring-parsley	G3,S3		WY
Cypripedium calceolus ssp *parviflorum*	small yellow ladys-slipper	G5,S1		UT
Cypripedium calceolus var. *pubescens*	large yellow ladies-slipper	G5,S1S2		WY
Cypripedium fasciculatum	clustered ladys-slipper	G4,S1		UT
Cypripedium montanum	mountain ladys-slipper	G4G5,S1		WY
Cystopteris utahensis	Utah bladderfern	G3?,S1		CO
Descurainia torulosa	Wyoming tansymustard	G1,S1	FS/BLM	WY
Dodecatheon dentatum var *utahense*	Utah shooting-star	G4T1,S1		UT
Draba borealis	Boreal draba	G4,S2	FS	WY
Draba brachystylis	Wasatch draba	G1G2,S1		UT
Draba fladnizensis	white arctic draba	G4,S1		MT
Draba fladnizensis var *pattersonii*	white arctic Whitlow-grass	G4T2T3,S2		WY
Draba globosa	round-fruited/rockcress draba	G3G5,S1S2	BLM	UT,WY
Draba juniperina	juniper whitlow-grass	G2G3Q,S2		UT
Draba maguirei sensu lato	Maguire whitlow-grass G3,S3			UT
Draba oligosperma	woods draba G5,S2			CO
Draba paysonii var. *paysonii*	Payson's draba	G5T3?,S2		WY
Draba pectinipila	comb-hair Whitlow-grass	G1Q,S1		WY
Draba porsildii	Porsilds draba	G3G4,S1		MT
Draba porsildii var *brevicula*	little snow draba	G3G4T1,S1		WY
Draba sp 2 (d. Burkei nom. Nov.)		G3T2,S2		UT
Drosera anglica	English sundew	G5,S2		MT
Dulichium arundinaceum	three-way sedge	G5,S1		WY
Eleocharis rostellata	beaked spikerush	G5,S2		MT
Eleocharis tenuis	slender spike-rush	G5,S1		ID
Elodea longivaginata	long sheath waterweed	G4G5,S2		MT
Epilobium palustre	swamp willow-weed	G5,S3	FS/BLM	ID
Epipactis gigantea	giant helleborine	G4, S1S2S3	FS	CO,UT,WY
Equisetum fluviatile	water horsetail	G5,S1		WY
Equisetum sylvaticum	woodland horsetail	G5,S1		WY
Erigeron allocotus	Bighorn fleabane	G3,S2S3		WY
Erigeron arenarioides	Utah fleabane	G3?,S3?		UT
Erigeron cronquistii	Cronquist daisy	G2,S2		UT
Erigeron formosissimus var *viscidus*	beautiful fleabane	G5T4,S1		MT
Erigeron garrettii	Garretts fleabane	G2,S2		UT

Erigeron lanatus	woolly fleabane	G3G4,S1	FS	WY
Erigeron radicatus	taprooted fleabane	G3,S2		WY
Erigeron wilkenii	Wilken fleabane	G1,S1		CO
Eriogonum brevicaule var *loganum*	Logan wild buckwheat	G2Q,S2		UT
Eriogonum saurinum	dinosaur buckwheat	G4T3,S1		CO
Eriogonum tumulosum	woodside buckwheat	G3,S2	BLM	CO
Eriophorum callitrix	sheathed cotton-grass	G5,S1		MT
Eriophorum scheuchzeri	Scheuchzer cotton-grass	G5,S1		WY
Eriophorum viridicarinatum	green keeled cotton-grass	G5,S2	FS	ID
Eritrichium howardii	Howard forget-me-not	G4,S1		WY
Eupatorium maculatum var *bruneri*	Joe-Pye weed	G5TU,S2		MT
Festuca hallii	Hall's fescue	G4,S1	FS	WY
Gentianopsis simplex	hikers gentian	G4,S1		MT
Grayia spinosa	spiny hopsage	G5,S2		MT
Gymnocarpium dryopteris	oak fern	G5,S1		WY
Haplopappus carthamoides var. *subsquarrosus*	beartooth large-flowered goldenweed	G4G5T2T3,S2		MT
Haplopappus macronema var. *linearis*	narrowleaf goldenweed	G4G5T3,S2	FS	WY
Haplopappus macronema var. *macronema*	discoid goldenweed	G4G5T4,S1		MT
Hedysarum occidentale var *canone*	canyon sweetvetch	G5T2,S2		UT
Helictotrichon mortonianum	alpine oatgrass	G4,S1		WY
Heterotheca depressa	Teton golden-aster	G3,S2		WY
Hutchinsia procumbens	Hutchinsia	G5,S1		MT
Hymenoxys lapidicola	rock hymenoxys	G1Q,S1		UT
Ipomopsis crebrifolia	compact gilia	G3G4,S3		WY
Ipomopsis spicata ssp. *robruthii*	Kirkpatrick"s ipomopsis	G4?T2,S2		WY
Ivesia utahensis	Utah ivesia	G2,S2		UT
Jamesia americana var *macrocalyx*	Wasatch jamesia	G5T2,S2		UT
Juncus albescens	three-flowered rush	G5,S2		MT
Juncus triglumis	three-flowered rush	G5,SU		MT
Juncus triglumis var. *albescens*	Northern white rush	G5T5,S1		WY
Juncus tweedyi	Tweedy's rush	G3Q,S1S2		ID,WY
Kobresia macrocarpa	large-fruited kobresia	G5,S1		MT
Kobresia schoenoides	Siberian kobresia	G5,S1		WY
Kobresia simpliciuscula	simple kobresia	G5,S1S2	FS	MT,UT,WY
Koenigia islandica	island koenigia	G4,S1		MT,WY
Lepidium huberi	Huber peppergrass	G1G2,S1S2		UT
Lepidium montanum var *alpinum*	alpine peppergrass	G5?T1,S1		UT
Leptodactylon caespitosum	leptodactylon	G3G4,S2		MT
Leptodactylon watsonii	Watsons prickly-phlox	G3,S1		WY
Lesquerella carinata var. *carinata*	keeled bladderpod	G3G4T3T4,S1		WY
Lesquerella fremontii	Fremont bladderpod	G2,S2		WY
Lesquerella garrettii	Garrett bladderpod	G2,S2		UT
Lesquerella lesicii	Lesicas bladderpod	G1,S1		MT
Lesquerella paysonii	Payson's bladderpod	G3,S2S3	FS/BLM	ID,WY
Lewisia rediviva	bitteroot	G5,S2		CO
Limnorchis zothecina	alcove bog orchid	G2,S1		CO
Lomatium attenuatum	taper-tip desert-parsley/ Absaroka biscuitroot	G3,S2		MT,WY
Lycopodiella inundata	northern bog clubmoss	G5,S2	FS	ID

Lymnaea stagnalis	swamp lymnaea	G5,S2?		UT
Mentzelia pumila	dwarf mentzelia	G4,S2		MT
Minuartia filiorum	three-branch stitchwort	G3G4,S1		WY
Moneses uniflora	one-flower wintergreen	G5,S4		UT
Muhlenbergia glomerata	marsh muhly	G5,S1	FS	WY
Musineon lineare	Rydbergs musineon	G2G3,S1		ID,UT
Musineon vaginatum	sheathed musineon	G3?,S2		WY
Oenothera acutissima	narrow-leaf evening primrose	G2,S2	BLM	CO
Oenothera flava var *acutissima*	narrow-leaf evening primrose	G2,S2		UT
Ophioglossum vulgatum	adders-tongue	G5,S1		WY
Oreocarya breviflora	short-flower cryptanth	G4,S1		CO
Oreocarya caespitosa	tufted cryptanth	G4,S2	BLM	CO
Oxytropis besseyi var *obnapiformis*	Bessey locoweed	G5T2,S2		CO
Oxytropis deflexa var *foliolosa*	pendent-pod crazyweed	G5T?,S1		MT
Paludella squarrosa		G3G5,S1		MT
Papaver kluanensis	alpine poppy	G3?Q, S1S2		MT,WY
Papaver radicatum ssp *kluanense*	alpine poppy	G5T3?,S1		UT
Parrya nudicaulis	naked-stemmed parrya	G5,S2	FS	WY
Parrya rydbergii	naked-stemmed wallflower	G2Q,S2		UT
Pedicularis contorta var *ctenophora*	coil-beaked lousewort	G5T3,S2		WY
Pedicularis pulchella	mountain lousewort	G3,S2		WY
Pellaea breweri	Brewers cliff-brake	G5,S2		CO
Pellaea glabella	smooth cliff-brake	G5,S2		UT
Pellaea suksdorfiana	smooth cliff-brake	G5T4?,S2		CO
Penstemon absarokensis	Absaroka beardtongue	G2,S2		WY
Penstemon acaulis var *acaulis*	stemless beardtongue	G2,S1		UT
Penstemon acaulis var *yampaensis*	Yampa/ penlands beardtongue	G3Q,S1S3		CO,UT
Penstemon angustifolius var *vernalensis*	vernal narrow-leaf penstemon	G5T3,S3		UT
Penstemon caryi	Cary beardtongue	G3,S2	FS	WY
Penstemon compactus	cache penstemon/ bear river range beardtongue	G2,S2	FS	ID,UT
Penstemon gibbensii	Gibbens beardtongue	G1,S1	BLM	CO
Penstemon goodrichii	Goodrich penstemon	G2,S2		UT
Penstemon paysoniorum	Payson beardtongue	G3,S3		WY
Penstemon platyphyllus	broadleaf penstemon	G2G3,S2S3		UT
Penstemon scariosus var *albifluvis*	White River penstemon	G4T1,S1	C	CO
Penstemon scariosus var *cyanomontanus*	blue mountain beardtongue/ plateau penstemon	G4T2,S2		CO,UT
Penstemon uintahensis	Uintah beardtongue	G3,S3		UT
Phippsia algida	icegrass	G5,S2		MT
Phlox opalensis	opal phlox	G3,S3	BLM	WY
Physaria acutifolia var *purpurea*		G5T2,S2		UT
Physaria lanata	woolly twinpod	G5T2,S2		WY
Physaria repanda	repand twinpod	G1?Q,S1?		UT
Physaria saximontana var. *saximontana*	Rocky Mountain twinpod	G3T2,S2		WY
Picea glaunca	white spruce	G5, S1		ID
Poa curta	short-leaved bluegrass	G4,S1		MT
Polygonum douglasii ssp *austinae*	Austins knotweed	G5T4,S2S3		MT
Potamogeton foliosus var *fibrillosus*	fibrous pondweed	G5T2T4,S1		UT
Potentilla hyparctica	Arctic cinquefoil	G4G5,S1		MT

Potentilla palustris	marsh cinquifoil	G5,S1		UT
Potentilla pensylvanica var *paucijuga*	few-leaflet cinquefoil	G5T1T2Q,S1		UT
Potentilla subjuga	twinleaf cinquefoil	G4,S2		WY
Potentilla uniflora	one-flower cinquefoil	G5,S1		MT
Primula egaliksensis	Greenland primrose	G4,S1	FS	WY
Primula incana	Jones'/mealy primrose	G4G5,S1S2		ID,MT
Primula maguirei	Maguire primrose	G1,S1	T	UT
Pyrrocoma carthamoides var. *subsquarrosa*	Absaroka goldenweed	G4G5T2T3,S2	FS	WY
Pyrrocoma integrifolia	entire-leaved goldenweed	G3?,S1		WY
Ranunculus jovis	Jove's buttercup	G4,S2		MT
Rubus acaulis	nagoonberry	G5,S1	FS	WY
Salicornia rubra	red glasswort	G4,S2	BLM	ID
Salix barrattiana	Barratt willow	G5,S1		MT
Salix candida	Hoary willow	G5, S2		ID
Salix glauca	gray willow	G4,S2		ID
Salix myrtillifolia var. *myrtillifolia*	myrtleleaf willow	G5T5,S1	FS	WY
Salix pseudomonticola	false mountain willow	G5?,S1	BLM	ID
Salix wolfii var *wolfii*	Wolfs willow	G5?T4,S3		MT
Sanicula graveolens	sierra sanicle	G4,S1	BLM	ID
Saussurea weberi	Weber's saw-wort	G3,S2	FS	WY
Saxifraga apetala	tiny swamp saxifrage	G3Q,S2		MT
Saxifraga hirculus	yellow marsh saxifrage	G5,S1		MT
Scheuchzeria palustris	pod grass	G5,S1S2	FS	ID,WY
Scirpus rollandii	Rolland bulrush	G3Q,S1	FS	WY
Scirpus subterminalis	water bulrush/clubrush	G4G5,S1S3	FS/BLM	ID,MT,WY
Scolochloa festucacea	sprangle-top	G5,S1		WY
Senecio amplectens var *holmii*	clasping groundsel	G4T?, S1		MT
Senecio eremophilus var *eremophilus*	cut-leaved groundsel	G5T5,S1		MT
Shoshonea pulvinata	shoshonea	G2G3,S1S2	FS	MT,WY
Sidalcea oregana	Oregon checker-mallow	G5,S1		MT
Silene kingii	King's campion	G2G4Q,S2		WY
Silene repens var. *australe*	creeping campion	G5T?,S1		WY
Sphenopholis intermedia	slender wedgegrass	G5,S1		MT
Spiranthes diluvialis	Ute ladies' tresses	G2,S1S2		CO,ID,UT
Spiranthes romanzoffiana	hooded ladies-tresses	G5,S?		UT
Stellaria crassifolia	fleshy stitchwort	G5,S1		MT
Stephanomeria fluminea	Teton wire-lettuce	G2?, S2		WY
Stephanomeria tenuifolia var *uintaensis*	narrow-leaved skeletonplant	G5T, S1		UT
Stipa lettermanii	Lettermans needlegrass	G5,S1		MT
Sullivantia hapemanii	Hapemans/Wyoming sullivantia	G3T2T3,S3	FS	WY
Taraxacum eriophorum	Rocky Mountain dandelion	G4,S2		MT
Thelypodium sagittatum ssp *sagittatum*	slender thelypody	G4T?,S2		MT
Thlaspi parviflorum	Small-flowered pennycress	G3,S2		MT
Torreyochloa pallida var. *fernaldii*	Fernald alkali-grass	G5?T4Q,S1		WY
Townsendia condensata var. *anomala*	North Fork Easter-daisy	G4T2,S2	FS	WY
Townsendia montana var *caelilinensis*	skyline townsendia	G4?T2T3,S2S3		UT
Trifolium andinum	mountain clover	G3,S1	BLM	CO
Viola beckwithii	Beckwith violet (bird-foot violet)	G4,S2		UT

Viola frank-smithii	Frank Smiths violet	G2,S2		UT
Zigadenus vaginatus	sheathed deathcamus	G2,S2		UT

Animal Species

Species Name	Common Name	G/S Rank	ESA/Sens	States
Bufo boreas	Boreal Toad	G4T4, S2	P/FS	MT,UT
Charina bottae	rubber boa	G5,S2S3		WY
Coluber constrictor	Mormon western yellowbelly racer	G5T5,S3		CO
Colligyrus greggi	Rocky Mountain duskysnail	G3G4,S1		UT
Corynorhinus townsendii	Townsend's big-eared bat	G4, S2?	PS/FS/BLM	ID,UT,WY
Diadophis punctatus	ringneck snake	G5,S1?	BLM	ID
Elaphe guttata	corn snake	G5,S2		UT
Euderma maculatum	spotted bat	G4,S1S2	FS/BLM	CO,MT,UT,WY
Fluminicola coloradoensis	Green River pebblesnail	G1G2,S1?		UT
Lasiurus blossevillii	western red bat	G5,S1		UT
Liochlorophis vernalis	smooth green snake	G5,S3		UT
Microtus richardsoni	water vole	G5,S2S3	FS	WY
Mustela nigripes	black-footed ferret	G1,S1	LE	WY
Myotis ciliolabrum	western small-footed myotis	G5,S4?	BLM	ID
Myotis evotis	long-eared myotis	G5,S3?	BLM	ID
Myotis thysanodes	fringed myotis	G4G5,S1BS1N	FS	UT,WY
Myotis volans	long-legged myotis	G5,S3?	BLM	ID
Myotis yumanensis	Yuma myotis	G5,S3?	BLM	ID
Oreohelix eurekensis	Eureka mountainsnail	G1,S1		UT
Oreohelix haydeni	lyrate mountainsnail	G2G3,S2?		UT
Oreohelix peripherica	deseret mountainsnail	G2,S2		UT
Oreohelix strigosa berryi	berry's mountainsnail	G5T2,S1S2		MT
Pacifastacus gambelii	Gambels crayfish	G4G5,S2		UT
Perognathus fasciatus callistus	olive-backed pocket mouse subsp.	G5T3T4,S2?		CO
Perognathus parvus	Great Basin pocket mouse	G5,S1?		CO
Plecotus townsendii pallescens	Townsends big-eared bat subsp.	G4T4,S2	BLM	CO
Pyrgulopsis kolobensis	Toquerville springsnail	G5,S?		UT
Pyrgulopsis transversa	southern Bonneville springsnail	G2,S1S2		UT
Rana luteiventris	Columbia spotted frog	G4,S2S3	P/FS	UT,WY
Rana pipiens	northern leopard frog	G5,S3	FS/BLM	ID,WY
Rana sylvatica	wood frog	G5,S2	FS	WY
Sorex merriami	Merriams shrew	G5,S2?		ID
Sorex nanus	dwarf shrew	G4,S1S2S3	FS	UT,WY
Spea intermontana	Great Basin spadefoot	G5,S3	BLM	CO
Spermophilus tridecemlineatus	thirteen-lined ground squirrel	G5,SH		UT
Spermophilus variegatus	rock squirrel	G5,S1	BLM	ID
Speyeria nokomis nokomis	Nokomis fritillary	G3T1,S2?		UT
Tamias umbrinus	Uinta chipmunk	G5,S1		ID

Class 2: Relatively broadly distributed species (i.e., not narrowly endemic) that are declining, highly vulnerable, or otherwise of high conservation interest. In this region, this class is restricted to "Partners in Flight" bird species. These are coarse-scale or regional-scale species and require some expansion of the traditional fine-filter approach.

Goal: Protect 100% of viable occurrences of G1/G2 species and at least 10 viable occurrences of all others.

Species Name	Common Name	G/S Rank	ESA/Sens	States
Accipeter gentilis	northern goshawk	G5,S2S3S4B	FS/BLM	ID,MT,WY
Aechmophorus occidentalis	western grebe	G5,S4BSZN		ID
Aegolius funereus	boreal owl	G5,S2S4		ID,MT,W
Amphispiza belli	sage sparrow			CO
Bubulcus ibis	cattle egret	G5,S2BSZN		ID
Bucephala albeola	bufflehead	G5,S1BS3BS3NS4N		ID,WY
Bucephala clangula	common goldeneye	G5,S3BS3N		ID
Bucephala islandica	Barrows goldeneye	G5,S3BS3N		ID
Calamospiza melanocorys	lark bunting	G5,S1?BSZN		ID
Carduelis psaltria	lesser goldfinch	G5,S1BSZN		ID
Charadrius alexandrinus	snowy plover	G4,S2S3B		UT
Charadrius montanus	mountain plover	G2,S2BSZN	PT/FS	WY
Chlidonias niger	black tern	G4,S1BS2BSZN	FS	ID,WY
Cygnus buccinator	trumpeter swan	G4,S1BS2BSZN	FS/BLM	ID,WY
Egretta thula	snowy egret	G5,S2BSZN		ID
Falco peregrinus anatum	peregrine falcon	G4T3,S1S2BSZN	LE-PDL	ID,MT,UT,WY
Gavia immer	common loon	G5,S1BS2N	FS	ID,WY
Glaucidium gnoma	northern pygmy-owl	G5,S4	BLM	ID
Grus americana	whooping crane	G1,SES1N	LE-XN	ID,WY
Grus canadensis	sandhill crane	G5,S1B		UT
Gymnorhinus cyanocephalus	pinyon jay	G5,S2?		ID
Haliaeetus leucocephalus	bald eagle	G4,S2BS3N	PS	ID,MT,UT,WY
Histrionicus histrionicus	harlequin duck	G4,S1S2B,SZN	FS	MT,WY
Larus pipixcan	franklins gull	G4G5,S2BSZN		ID,MT
Loxia leucoptera	white-winged crossbill	G5,S1BS2N		WY
Melanerpes lewis	Lewis woodpecker	G5 S2B SZN	FS	WY
Numenius americanus	long-billed curlew	G5,S3BSZN	BLM	ID
Nycticorax nycticorax	black-crowned night-heron	G5,S2S3BSZN		ID
Otus flammeolus	flammulated owl	G4, S3B, SZN		ID,WY
Otus kennicottii	western screech owl	G5,S2		WY
Pandion haliaetus	osprey	G5,S1S2B		UT
Pelecanus erythrorhynchos	American white pelican	G3,S1BSZN		WY
Picoides arcticus	black-backed woodpecker	G5,S3	FS	WY
Picoides tridactylus	three-toed woodpecker	G5,S2S3		UT
Plegadis chihi	white-faced ibis	G5,S1BS2BSZN		ID
Podiceps auritus	horned grebe	G5,S1?		ID
Podiceps grisegena	red-necked grebe	G5,S3BSZN		ID
Podiceps nigricollis	eared grebe	G5,S4BSZN		ID
Progne subis	purple martin	G5,S1?BSZN		ID
Quiscalus quiscula	common grackle	G5,S2BSZN		ID

Selasphorus rufus	rufous hummingbird	G5,S2BSZN		WY
Sterna caspia	Caspian tern	G5,S1BSZN		WY
Sterna forsteri	Forsters tern	G5,S2BSZN		ID
Strix nebulosa	great gray owl	G5,S2S3	FS/BLM	ID,WY
Tympanuchus phasianellus columbianus	Columbian sharp-tailed grouse	G4T3,S3	FS/BLM	ID
Tympanuchus phasianellus	sharp-tailed grouse	G4,S1S2		UT
Vermivora virginiae	Virginias warbler	G5,S2BSZN	BLM	ID
Vireo vicinior	gray vireo	G4,S2BSZN		CO

Class 3. Focal species: broadly-distributed (or historically so) animal species that are declining, highly vulnerable, ecologically important, or otherwise of high conservation interest. These are coarse-scale or regional-scale species, many of which serve as keystone species, umbrella species, or indicators of ecological integrity. They are addressed through habitat modeling and population viability analysis that extrapolate beyond known occurrences.

Goal: Protect habitat capable of supporting at least 50-70% of the population of each focal species that currently could be supported in the region, as identified by habitat suitability modeling (50% for elk, 70% for other focal species).

Species Name	Common Name	G/S Rank	ESA	States
Canis lupus	gray wolf	G4, S2S3	Experimental	MT,ID,WY
Cervus elaphus	elk			MT,ID,WY,UT
Felis lynx	lynx	G5T, S2S1	Threatened	MT,ID,WY
Gulo gulo	wolverine	G4, S2S1		MT,ID,WY,UT
Ursus arctos	grizzly bear	G4T3, S1S3	Threatened	MT,ID,WY

Class 4: Coarse-scale and regional-scale aquatic species (primarily animals) associated with streams or lakes.

Goal: Protect 100% of viable occurrences of G1/G2 species and at least 10 viable occurrences of all others.

Species Name	Common Name	G/S Rank	ESA/Sens	States
Catostomus discobolus	bluehead sucker	G4,S2S3		WY
Catostomus latipinnis	flannelmouth sucker	G3G4,S3		WY
Chasmistes liorus	June sucker	G1,S1	E	UT
Cottus beldingi	Paiute sculpin	G5,S1S2		UT
Cottus extensus	Bear Lake sculpin	G1,S1		UT
Gila copei	leatherside chub	G3G4,S2		UT,WY
Gila cypha	humpback chub	G1,S1	LE	CO,UT
Gila elegans	bonytail	G1,S1	E	UT
Gila robusta	roundtail chub	G2G3,S2	BLM	CO,UT
Iotichthys phlegethontis	least chub	G1,S1		UT
Oncorhynchus clarki bouvieri	Yellowstone cutthroat trout	G4T2,S2	FS	WY

Oncorhynchus clarki lewisi	westslope cutthroat trout	G4T3,S1S3	FS	WY
Oncorhynchus clarki pleuriticus	Colorado River cutthroat trout	G4T3,S2	FS	UT,WY
Oncorhynchus clarki utah	Bonneville cutthroat trout	G4T2,SS2	FS	UT,WY
Oncorhynchus clarki spp 2	Snake River fine-spotted CT	G4T1T2Q,S1	FS	WY
Ptychocheilus lucius	Colorado pikeminnow	G1T?Q,S1	LE	CO,UT
Rhinichthys osculus thermalis	Kendall warm springs dace	G5T1,S1	LE	WY
Xyrauchen texanus	razorback sucker	G1,S1	LE	CO

Class 5: Plant communities with restricted distributions globally (G1/G2) or which are endemic to or disjunct in the ecoregion, declining, highly vulnerable, or otherwise of high conservation interest. These are typically small-patch communities, although some may have been large-patch or matrix communities in the past. A traditional TNC fine-filter approach focused on relatively small sites or portfolios of such sites is appropriate in most cases. (Matrix communities are better addressed in Class 6.)

Goal: Protect 100% of viable occurrences of G1/G2 communities and at least 10 viable occurrences of other communities (i.e., assuming that many exist and have been mapped).

Plant Community	G/S Rank	Type	States
Abies lasiocarpa/Acer glabrum subalpine fir/mountain maple	G5,S3	Forest	ID
Abies lasiocarpa/Acer glabrum Pachistima myrsinites phase subalpine fir/mountain maple pachistima phase	G5,S3	Forest	ID
Abies lasiocarpa/Calamagrostis canadensis subalpine fir/bluejoint reedgrass	G5,S3	Forest	ID
Abies lasiocarpa/Calamagrostis rubescens subalpine fir/pinegrass	G5,SP	Forest	ID,WY
Abies lasiocarpa/Calamagrostis rubescens Calamagrostis rubescens phase subalpine fir/pinegrass pinegrass phase	G5,S3	Forest	ID
Abies lasiocarpa/Osmorhiza chilensis Pachistima myrsinites phase subalpine fir/mountain sweet-root pachistima phase	G4,S3	Forest	ID
Abies lasiocarpa / Physocarpus malvaceus subalpine fir/mountain ninebark	G4G5, S2	Forest	ID
Abies lasiocarpa/Ribes montigenum subalpine fir/mountain gooseberry	G5,S5	Forest	ID
Abies lasiocarpa/Shepherdia canadensis subalpine fir/buffalo-berry	G1?,S1	Forest	ID
Abies lasiocarpa/Spiraea betulifolia subalpine fir/white spiraea	G4,S3	Forest	WY
Abies lasiocarpa/Symphoricarpos albus subalpine fir/common snowberry	G4,S2	Forest	ID
Abies lasiocarpa/Vaccinium caespitosum subalpine fir/dwarf huckleberry	G5,S3	Forest	ID,WY
Abies lasiocarpa/Vaccinium globulare Pachistima myrsinites phase subalpine fir/blue huckleberry pachistima phase	G5,S4	Forest	ID
Abies lasiocarpa/Vaccinium globulare Vaccinium globulare phase subalpine fir/blue huckleberry blue huckleberry phase	G5,S4	Forest	ID,WY
Abies lasiocarpa/Vaccinium globulare Vaccinium scoparium phase subalpine fir/blue huckleberry grouse whortleberry phase	G5,S4	Forest	ID
Abies lasiocarpa/Vaccinium scoparium Calamagrostis rubescens phase subalpine fir/grouse whortleberry pinegrass phase	G5,S5	Forest	ID
Abies lasiocarpa/Vaccinium scoparium Vaccinium scoparium phase subalpine fir/grouse whortleberry grouse whortleberry phase	G5,S5	Forest	ID
Acer grandidentatum/Calamagrostis rubescens bigtooth maple/pinegrass	G2,S2	Forest	ID
Acer grandidentatum/Juniperus scopulorum bigtooth maple/rocky mountain juniper	G2?,S1	Forest	ID
Acer grandidentatum/Osmorhiza chilensis bigtooth maple/mountain sweet-root	G2?,S1	Forest	ID
Acer negundo/Cornus sericea box-elder/red-osier dogwood	G3?,S1	Forest	ID
Acer negundo/Osmorhiza chilensis box-elder/mountain sweet-root	G2?,S1	Forest	ID

Agropyron spicatum-Poa secunda bluebunch wheatgrass-sandbergs bluegrass	G2G3	Grassland	ID
Alnus incana/Cornus sericea mountain/speckled alder/red-osier dogwood	G3Q,S3	Shrubland	ID,WY
Alnus incana / Equisetum arvense	G3?	Shrubland	WY
Alnus incana/Ribes hudsonianum mountain alder/northern black current	G3,S3	Shrubland	ID
Artemisia arbuscula arbuscula/Agropyron spicatum low sagebrush/bluebunch wheatgrass	G5,S3	Shrubland	UT
Artemisia cana/Deschampsia cespitosa silver sagebrush/tufted hairgrass	G2G3,S3	Shrubland	ID
Artemisia cana/Poa pratensis silver sage/Kentucky bluegrass	S5	Shrubland	ID
Artemisia ludoviciana prairie sage	G3,S2	Shrubland	ID
Artemisia nova/Agropyron spicatum black sagebrush/bluebunch wheatgrass	G5,S3	Shrubland	ID
Artemisia nova/Poa secunda black sagebrush/Sandbergs bluegrass	G3,S3	Shrubland	ID
Artemisia nova/Pseudoroegneria spicata western slope sagebrush	G5,S2?	Shrubland	CO
Artemisia nova/Stipa comata western slope sagebrush	G4,S2?	Shrubland	CO
Artemisia tridentata tridentata/Elymus cinereus basin big sagebrush/Great Basin wildrye	G2,S1	Shrubland	ID
Artemisia tridentata ssp. tridentata / Pseudoroegneria spicata basin big sagebrush/bluebunch wheatgrass	G2G4	Shrubland	WY
Artemisia tridentata vaseyana-Symphoricarpos oreophilus/Agropyron spicatum mountain big sagebrush-mountain snowberry/bluebunch wheatgrass	G5,S3	Shrubland	ID
Artemisia tridentata vaseyana-Symphoricarpos oreophilus/Festuca idahoensis mountain big sagebrush-mountain snowberry/Idaho fescue	G4,S4	Shrubland	ID
Artemisia tridentata vaseyana/Agropyron spicatum mountain big sagebrush/bluebunch wheatgrass	G4,S4	Shrubland	ID
Artemisia tridentata vaseyana/Bromus carinatus mountain big sagebrush/California brome	G4,S3	Shrubland	UT
Artemisia tridentata vaseyana/Elymus cinereus mountain big sagebrush/Great Basin wildrye	G4?,S2	Shrubland	ID
Artemisia tridentata vaseyana/Festuca idahoensis mountain big sagebrush/Idaho fescue	G5,S4	Shrubland	ID
Artemisia tridentata vaseyana/Leucopoa kingii mountain big sagebrush/spike-fescue	G3,S3	Shrubland	ID
Atriplex confertifolia/Stipa comata cold desert shrublands	G1G2,S1S2	Shrubland	CO
Betula glandulosa/Carex simulata bog birch/short-beaked sedge	G2,S2	Shrubland	ID
Betula occidentalis water birch cover type	G3Q,S2	Shrubland	ID
Betula occidentalis/Cornus sericea water birch/red-osier dogwood	G2G3,S2	Shrubland	ID,WY
Betula occidentalis /mesic forb water birch/mesic forb	G3,S1	Shrubland	ID
Carex amplifolia association			ID
Carex Aquatilis water sedge	G5,S4	Herbaceous	ID
Carex buxbaumii Buxbaums sedge	G3,S1	Herbaceous	ID
Carex lanuginosa woolly sedge	G3?,S2	Herbaceous	ID,WY
Carex lasiocarpa slender sedge	G4,S2	Herbaceous	ID
Carex limosa mud sedge	G3,S1	Herbaceous	ID
Carex nebrascensis Nebraska sedge	G4,S3	Herbaceous	ID
Carex praegracilis clustered field sedge	G2G3Q,S2	Herbaceous	ID
Carex rupestris - Potentilla ovina curly sedge-sheep cinquefoil	G3	Herbaceous	WY
Carex simulata short-beaked sedge	G4,S2	Herbaceous	ID
Carex utriculata bladder sedge	G5,S4	Herbaceous	ID,WY
Carex vesicaria inflated sedge	GU,S3	Herbaceous	ID
Cercocarpus ledifolius/Agropyron spicatum curl-leaf mountain mahogany/bluebunch wheatgrass	G5,S4	Shrubland	ID,UT
Cercocarpus ledifolius/Leucopoa kingii curl-leaf mountain mahogany/spike-fescue	G3,S3	Shrubland	ID
Cercocarpus ledifolius/pseudoroegneria spicata phase artr mixed mountain shrublands			

	GU,S?	Shrubland	CO
Cornus sericea red-osier dogwood	G4Q,S3	Shrubland	ID
Cornus sericea/Galium triflorum red-osier dogwood/sweetscented bedstraw	G3,S2	Shrubland	ID,WY
Cornus sericea/Heracleum lanatum red-osier dogwood/cow parsnip	G3,S2	Shrubland	ID
Crataegus Douglasii/Heracleum lanatum black hawthorn/cow parsnip	G2,S1	Shrubland	ID
Deschampsia cespitosa tufted hairgrass	G4?,S3	Herbaceous	ID,WY
Deschampsia cespitosa - Carex microptera tufted hairgrass-small wing sedge	G2G3	Herbaceous	WY
Deschampsia cespitosa - Phleum alpinum tufted hairgrass-mountain timothy herbaceous vegetation	G3?	Herbaceous	WY
Distichlis stricta interior saltgrass	G5,S4	Herbaceous	ID
Dryas octopetala eight petal mountain-avens	G3?	Herbaceous	WY
Dulichium arundinaceum three way sedge	G3?,S2	Herbaceous	ID
Elaeagnus commutata American silverberry	G2,S2	Shrubland	ID
Eleocharis acicularis needle spike-rush	G4?,S3	Herbaceous	ID
Eleocharis palustris creeping spikerush	G5,S3	Herbaceous	ID
Eleocharis pauciflora-Carex aquatilis Carex livida phase few-flowered spikerush-water sedge pale sedge phase	GQ,S2	Herbaceous	ID
Elymus cinereus Great Basin wildrye	G2G3Q,S3	Grassland	ID
Festuca idahoensis - Deschampsia cespitosa Idaho fescue-tufted hairgrass	G3	Herbaceous	WY
Festuca idahoensis - Festuca kingii Idaho fescue-spike-fescue	G2?	Herbaceous	WY
Festuca idahoensis - Potentilla diversifolia	G3	Herbaceous	WY
Geum rossii - Selaginella densa Ross avens-dense spike-moss	G2G3	Herbaceous	WY
Geum rossii - Trifolium spp. Ross avens-trifolium spp.?	G3	Herbaceous	WY
Glyceria borealis northern mannagrass	G4,S1	Herbaceous	ID
Hordeum jubatum foxtail barley	G4,S5	Herbaceous	ID
Juncus balticus Baltic rush	G5,S4	Herbaceous	ID,WY
Juniperus osteosperma/artemisia arbuscula arbuscula/agropyron spicatum Utah juniper/low sagebrush/bluebunch wheatgrass	G2,S2		ID
Ligusticum filicinum - Delphinium occidentale fearnleaf wild lovage-dunce-cap larkspur	G3	Herbaceous	WY
Muhlenbergia richardsonis mat muhly	GU,SU	Grassland	ID
Nuphar polysepalum pond lily	G5,S4	Aquatic	ID
Phalaris arundinacea reed canarygrass	G4,S5	Grassland	ID
Picea engelmannii/Calamagrostis canadensis Engelmanns spruce/bluejoint reedgrass	G4,S4	Forest	ID
Picea engelmannii/Cornus sericea Engelmann spruce/red-osier dogwood	G3,S2	Forest	ID,WY
Picea engelmannii/Equisetum arvense Engelmann spruce/common horsetail	G4, S2	Forest	ID,WY
Picea engelmannii/Hypnum revolutum Engelmanns spruce/revolute hypnum moss	G2	Forest	WY
Picea glauca/Carex disperma white spruce/softleaf sedge	G1,S1	Forest	ID
Picea glauca/Carex utriculata white spruce/bladder sedge	G1,S1	Forest	ID
Picea glauca/Equisetum arvense white spruce/common horsetail	G4,S1	Forest	ID
Pinus albicaulis/Carex rossii Pinus contorta phase whitebark pine/Ross sedge lodgepole pine phase	G?,S?	Forest	ID
Pinus albicaulis/Juniperus communis	G4?	Woodland	WY
Pinus albicaulis/Vaccinium scoparium whitebark pine/grouse whortleberry	G4,S4	Forest	WY
Pinus contorta/Calamagrostis canadensis lodgepole pine/bluejoint reedgrass	G5Q,S5	Forest	ID,WY
Pinus contorta/Calamagrostis rubescens lodgepole pine/pinegrass	G5,S4	Forest	ID,WY
Pinus contorta/Spiraea betulifolia lodgepole pine/white spiraea	G3G4,S2	Forest	ID
Pinus contorta/Vaccinium caespitosum lodgepole pine/dwarf huckleberry	G5,S4	Forest	WY
Pinus contorta/Vaccinium scoparium lodgepole pine/grouse whortleberry	G5,S5	Forest	ID
Pinus edulis/Cercocarpus ledifolius mesic western slope pinyon-juniper	G3,S3	Woodland	CO,WY

Pinus edulis/Pseudoroegneria spicata xeric western slope pinyon-juniper	G4,S4	Woodland	CO
Pinus flexilis/Cercocarpus ledifolius limber pine/curl-leaf mountain mahogany	G3G4,S2	Woodland	ID
Pinus flexilis / Festuca idahoensis	G5	Woodland	WY
Pinus flexilis / Juniperus communis	G5	Woodland	WY
Pinus flexilis/Leucopoa kingii limber pine/spike-fescue	G4,S3	Woodland	ID
Poa palustris fowl bluegrass	S5	Grassland	ID
Poa pratensis Kentucky bluegrass	S5	Grassland	ID
Polygonum amphibium water ladysthumb	G3Q,S4	Herbaceous	ID
Populus angustifolia/Betula occidentalis narrow-leaf cottonwood/water birch	G1G3,S1	Woodland	ID
Populus angustifolia/Chrysopsis villosa narrow-leaf cottonwood/hairy goldenaster	G3,S2	Woodland	ID
Populus angustifolia/Cornus sericea narrowleaf cottonwood/red-osier dogwood	G4,S1	Woodland	CO,ID
Populus angustifolia/Elaeagnus commutata narrow-leaf cottonwood/American silverberry	G2,S2	Woodland	ID
Populus angustifolia/Poa pratensis narrow leaf cottonwood/Kentucky bluegrass	S5	Woodland	ID
Populus angustifolia / Prunus virginiana narrow-leaf cottonwood/choke cherry	G2G3	Forest	WY
Populus angustifolia/Rosa woodsii	G2G3	Forest	WY
Populus deltoides ssp. w*islizenii/Rhus trilobata* Fremonts cottonwood	G2,S2	Forest	CO
Populus tremuloides/Amelanchier alnifolia-Symphoricarpos oreophilus/Calamagrostis rubescens quaking aspen/western serviceberry-mountain snowberry/pinegrass	G4,S4	Forest	ID
Populus tremuloides/Cornus sericea quaking aspen/red-osier dogwood	G4,S4	Forest	ID
Populus tremuloides / Lupinus argenteus quaking aspen/silver-stem lupine	G2?	Forest	WY
Populus tremuloides-Pseudotsuga menziesii/Amelanchier alnifolia	G3?,S?	Forest	ID
Populus tremuloides-Pseudotsuga menziesii/Calamagrostis rubescens quaking aspen-Douglas-fir/pinegrass	G?,S?	Forest	ID
Populus tremuloides/Salix scouleriana quaking aspen/Scoulers willow	G4,S3	Forest	ID
Populus tremuloides/Symphoricarpos oreophilus/Calamagrostis rubescens quaking aspen/mountain snowberry/pinegrass	G5,S4	Forest	ID
Populus tremuloides/Thalictrum fendleri	G5,S?	Forest	ID
Prunus virginiana/Artemisia tridentata vaseyana-Symphoricarpos oreophilus chokecherry/mountain big sagebrush-mountain snowberry	G?,S4	Shrubland	ID
Pseudotsuga menziesii/Acer glabrum Douglas-fir/mountain maple	G4,S3	Forest	ID,UT
Pseudotsuga menziesii/Arnica cordifolia Douglas-fir/heartleaf arnica	G4,S3	Forest	ID
Pseudotsuga menziesii/Berberis repens Douglas-fir/low Oregon grape	G5,S5	Forest	ID
Pseudotsuga menziesii/Calamagrostis rubescens Calamagrostis rubescens phase Douglas-fir/pinegrass pinegrass phase	G5,S3	Forest	ID
Pseudotsuga menziesii/Calamagrostis rubescens Pachistima myrsinites phase Douglas-fir/pinegrass pachistima phase	G5,S2?	Forest	ID
Pseudotsuga menziesii/Calamagrostis rubescens Douglas-fir/pinegrass	G5,S5	Forest	ID
Pseudotsuga menziesii/Cercocarpus ledifolius Douglas-fir/curl-leaf mountain mahogany	G4,S3	Forest	ID
Pseudotsuga menziesii/Cornus sericea Douglas-fir/red-osier dogwood	G4,S4	Forest	ID
Pseudotsuga menziesii/Juniperus communis Douglas-fir/common juniper	G5Q,S3	Forest	ID
Pseudotsuga menziesii/Osmorhiza chilensis Douglas-fir/mountain sweet-root	G4G5,S3	Forest	ID,UT
Pseudotsuga menziesii/Physocarpus malvaceus Pachistima myrsinites phase Douglas-fir/mountain ninebark pachistima phase	G5,S3	Forest	ID
Pseudotsuga menziesii/Physocarpus malvaceus Douglas-fir/mountain ninebark	G5,S5	Forest	ID
Pseudotsuga menziesii/Spiraea betulifolia Calamagrostis rubescens phase Douglas-fir/white spiraea pinegrass phase	G5,S3	Forest	ID
Pseudotsuga menziesii/Spiraea betulifolia Spiraea betulifolia phase Douglas-fir/white spiraea white spiraea phase	G5,S3	Forest	ID
Pseudotsuga menziesii/Spiraea betulifolia Douglas-fir/white spiraea	G5,S5	Forest	ID

Pseudotsuga menziesii/Symphoricarpos oreophilus Douglas-fir/mountain snowberry	G5,S3	Forest	ID
Salix arctica / Polygonum bistortoides	G2G3	Shrubland	WY
Salix bebbiana Bebb willow	G?,S?	Shrubland	ID
Salix boothii / *Calamagrostis canadensis* Booth willow/bluejoint reedgrass	G3G4Q,S3	Shrubland	ID
Salix boothii / *Carex aquatilis* Booth willow/water sedge	G3,S3?	Shrubland	ID
Salix boothii/Carex utriculata Booth willow/bladder sedge	G4,S4	Shrubland	ID
Salix boothii / *Equisetum arvense* Booth willow/common horsetail	G3,S2	Shrubland	ID
Salix boothii / Mesic Forbs Booth willow/mesic forb	G3,S3?	Shrubland	ID,WY
Salix boothii / Mesic Graminoids Booth willow/mesic graminoid	G3?,S3?	Shrubland	ID,WY
Salix boothii/Poa pratensis Booth willow/Kentucky bluegrass	S5	Shrubland	ID
Salix drummondiana / *Carex utriculata* Drummonds willow/bladder sedge	G3,S3	Shrubland	ID
Salix eastwoodiae / Carex aquatilis	G2	Shrubland	WY
Salix exigua /barren coyote willow/barren	G3?,S4	Shrubland	ID
Salix exigua / Mesic Forbs coyote willow/mesic forb	G2?,S2?	Shrubland	ID
Salix exigua /Mesic graminoid coyote willow/mesic graminoid	G3Q,S3?	Shrubland	ID
Salix exigua/Poa pratensis coyote willow/Kentucky bluegrass	S5	Shrubland	ID
Salix geyeriana/Calamagrostis canadensis Geyer willow/bluejoint reedgrass	G5,S4	Shrubland	ID
Salix geyeriana/Carex aquatilis Geyer willow/water sedge	G3?,S3?	Shrubland	ID
Salix geyeriana/Carex utriculata Geyer willow/bladder sedge	G5,S4	Shrubland	ID
Salix geyeriana / Mesic Forbs Geyer willow/mesic forb	G3,S3	Shrubland	ID,WY
Salix geyeriana / Mesic Graminoids Geyer willow/mesic graminoid	G2G3Q,S5	Shrubland	ID
Salix geyeriana/Poa palustris Geyer willow/fowl bluegrass	G2?,S5	Shrubland	ID
Salix glauca	G3?	Shrubland	WY
Salix lasiandra/ mesic forb whiplash willow/mesic forb	G?,SP	Shrubland	ID
Salix lasiandra/Poa pratensis whiplash willow/Kentucky bluegrass	S5	Shrubland	ID
Salix planifolia / Deschampsia cespitosa	G2G3	Shrubland	WY
Salix planifolia monica/Carex aquatilis-Carex utriculata planeleaf willow/water sedge-bladder sedge	G3Q,S3	Shrubland	ID
Salix reticulata / Caltha leptosepala	G2	Shrubland	WY
Salix wolfii/Carex aquatilis Wolfs willow/water sedge	G4,S4	Shrubland	ID
Salix wolfii/Carex utriculata Wolfs willow/bladder sedge	G4,S4	Shrubland	ID
Salix wolfii / Deschampsia cespitosa Idaho willow/tufted hairgrass	G3	Shrubland	WY
Salix wolfii / Mesic Forbs Idaho willow/mesic forbs	G3	Shrubland	WY
Sarcobatus vermiculatus/Distichlis stricta greasewood/interior saltgrass	G4,S1		ID
Scirpus acutus hardstem bulrush	G5,S4	Herbaceous	ID
Scirpus americanus threesquare bulrush	G1Q,S1	Herbaceous	ID
Scirpus maritimus akali bulrush	G4,S3	Herbaceous	ID
Scirpus validus softstem bulrush	G4,S2	Herbaceous	ID,WY
Spartina gracilis akali cordgrass	GU,SU	Herbaceous	ID,WY
Thermal springs aquatic community	G3?,S2	Aquatic	ID
Travertine barrens	G2?,S2?	Barrens	ID
Travertine springs desert aquatic ecosystem	G1,S1	Aquatic	ID
Typha latifolia common cattail	G5,S4	Herbaceous	ID
Valley peatland floating mat	G3,S1	Peatland	ID

Class 6: Ecological systems—GAP vegetation types, those vegetation types stratified by physical (abiotic; geoclimatic) habitats defined by a cluster analysis of climatic and edaphic variables, and aquatic (stream reach) types.

Goal: Represent at least 35% of the area (in hectares) of each GAP vegetation wetland habitat type (lowland riparian, mountain riparian, water, wetland, wet meadow), 25% of other GAP vegetation types, 10% of each combined vegetation/physical habitat type, and 35% of the length of each aquatic (stream) habitat type in the reserve network. Aquatic habitat types and methods of their classification are described in Appendix D. There were 581 different combinations of aquatic macrohabitats and ecological systems, too many to list here.

The 44 Gap Analysis Program vegetation habitat types:

Code	Vegetation Type	Total Area	Protected Area	Goal
1	Alpine Fir	210578	91146	0
2	Alpine Fir/Doug Fir	12038	290	2720
3	Alpine Fir/Lodgepole	308657	53503	23661
4	Alpine Fir/Spruce	435764	181898	0
5	Alpine Fir/Whitebark	14016	1779	1725
6	Doug Fir	485276	119282	2037
8	Doug Fir/Limber Pine	330	270	0
9	Doug Fir/Lodgepole Pine	64353	20468	0
11	Doug Fir or White Fir	103190	12496	13302
13	Juniper,Utah	170300	22805	19770
14	Juniper,Western	2194	565	0
15	Lodgepole	1683782	667523	0
16	Lodgepole/Aspen	16656	365	3799
18	Pinyon	33012	3744	4509
19	Pinyon-Juniper	324987	112899	0
20	Ponderosa Pine	59486	5402	9470
25	Spruce	92244	62863	0
26	Whitebark/Limber Pine	440377	298773	0
29	Aspen	693396	52406	120943
30	Aspen/Conifer	217654	42316	12098
31	Maple	65965	7173	9318
32	Mountain Mahogany	2832	152	556
33	Oak	245543	14500	46886
34	Bitterbrush	24660	2168	3997
36	Burn_Shrub	136209	125260	0
39	Greasewood	2549	450	187
43	Montane Shrub	317274	64245	15074
44	Mountain Sage	1306010	167622	158881
46	Sagebrush	350049	72538	14974
47	Sagebrush Steppe	252901	33625	29600
48	Salt Desert Scrub	39203	5588	4213

Code	Vegetation Type	Total Area	Protected Area	Goal
50	Alpine Herbaceous	434398	270913	0
51	Burn_herbaceous	22216	16399	0
53	Desert Grassland	2549	288	349
54	Dry Meadow	179227	38197	6610
55	Grassland	690825	123941	48765
56	Perennial Grass Montane	75861	45609	0
57	Tall Forb Montane	46924	16825	0
58	Wet Meadow	32775	8122	3349
59	Barren	448089	325801	0
62	Water	134232	94832	0
64	Lowland Riparian	30782	9426	1348
65	Mt. Riparian	140064	28391	20631
66	Wetland	45545	16126	0

Physical habitat types are based on mean annual precipitation, mean spring (May and June) precipitation, mean annual low temperature, mean annual high temperature, the difference between winter mean low temperature and summer mean high temperature, mean annual growing degree days, soil depth, soil water-holding capacity, and soil organic carbon content. Descriptions refer to variables with mean values within the habitat type greater than one standard deviation from the GYE mean: 'high' and 'deep' refer to values between one and two standard deviations above the regional mean; 'low' and 'shallow to values between one and two standard deviations below the regional mean; 'very high' and 'extra high' refer to values between two and three standard deviations and greater than three standard deviations above the regional mean, respectively; 'very low' and 'very shallow' refer to values between two and three standard deviations below the regional mean; and 'extra low' refers to values more than three standard deviations below the regional mean. Variables not included in type descriptions have mean values in the habitat type area that are within one standard deviation of the mean value for the entire GYE. There are 43 physical habitat types in the region. GAP vegetation types were stratified by physical habitat types, and any resulting combined type with a total area less than 1% of the area of the original GAP vegetation type was eliminated. This resulted in 723 combined vegetation/physical habitat types.

Code	Description
1	High annual precipitation, extra low annual minimum temperature, very low annual maximum temperature, high winter-summer temperature contrast, low growing degree days, shallow soil, low soil water capacity, low soil carbon
2	Low annual minimum temperature, low annual maximum temperature, low winter-summer temperature contrast, low growing degree days, shallow soil
3	Very low annual minimum temperature, very low annual maximum temperature, low winter-summer temperature contrast, low growing degree days, low soil water capacity, low soil carbon
4	Low annual minimum temperature, low annual maximum temperature, very low winter-summer temperature contrast, low growing degree days, shallow soil, low soil water capacity, low soil carbon
5	Very high annual precipitation, very high spring precipitation, low annual maximum temperature, low winter-summer temperature contrast, low growing degree days, shallow soil, low soil water capacity

Code	Description
6	High annual precipitation, low annual maximum temperature, low winter-summer temperature contrast, low growing degree days, deep soil
7	Shallow soil, low soil water capacity
9	Very high annual precipitation, high spring precipitation, low annual minimum temperature, low annual maximum temperature, high growing degree days
10	Low spring precipitation, very low annual minimum temperature, low annual maximum temperature, high winter-summer temperature contrast, low growing degree days, deep soil, low soil water capacity
11	High annual precipitation, high spring precipitation, low annual minimum temperature, low annual maximum temperature, low growing degree days, shallow soil, low soil water capacity, low soil carbon
12	Low annual minimum temperature, low annual maximum temperature, low winter-summer temperature contrast, low growing degree days, deep soil, low soil water capacity
13	High annual precipitation, very low annual minimum temperature, low annual maximum temperature, very high winter-summer temperature contrast, low growing degree days
14	High winter-summer temperature contrast, low soil water capacity
15	Low annual precipitation, low spring precipitation, low annual minimum temperature, extra high winter-summer temperature contrast
16	Low annual minimum temperature, low annual maximum temperature, low growing degree days, deep soil, low soil water capacity
17	Shallow soil, extra low soil water capacity, low soil carbon
18	Low annual minimum temperature, high winter-summer temperature contrast, deep soil
19	Low annual minimum temperature, low growing degree days, shallow soil
20	Deep soil, low soil water capacity
21	Very high spring precipitation, low winter-summer temperature contrast, low soil water capacity
22	High spring precipitation, deep soil
23	High annual precipitation, very low winter-summer temperature contrast
24	Average by all measures
25	Shallow soil
26	High spring precipitation
27	Low annual precipitation, deep soil
28	High annual minimum temperature, very low winter-summer temperature contrast
29	High soil water capacity
30	Low annual precipitation, high annual minimum temperature, high annual maximum temperature, high growing degree days, shallow soil
31	Low annual precipitation, high annual maximum temperature, high growing degree days, deep soil, high soil water capacity
32	Low annual precipitation, low spring precipitation, high annual maximum temperature, high winter-summer temperature contrast, high growing degree days, very shallow soil
33	Low annual precipitation, low spring precipitation, high annual maximum temperature, high winter-summer temperature contrast, high growing degree days, deep soil
34	High annual precipitation, high annual minimum temperature, high growing degree days
35	Deep soil, high soil water capacity
36	Low spring precipitation, deep soil
37	Deep soil, high soil carbon
38	Low winter-summer temperature contrast, deep soil, very high soil carbon
39	Deep soil, very high soil water capacity, very high soil carbon
40	High growing degree days, deep soil, high soil water capacity, high soil carbon

Code	Description
41	Low spring precipitation, high annual minimum temperature, high annual maximum temperature, high growing degree days, deep soil, high soil water capacity, very high soil carbon
42	High annual minimum temperature, high annual maximum temperature, high growing degree days, deep soil
43	Deep soil, high soil water capacity, extremely high soil carbon
99	Water

Appendix B: FOCAL SPECIES

This appendix provides supplementary information on the modeling approaches applied in this study, the models for individual species, and the detailed methodology.

MODELING AS A CONSERVATION PLANNING TOOL

Spatial modeling of focal species distribution serves two distinct purposes. On the one hand, we can analyze the association between species and characteristics of the environment in order to interpret their habitat needs. For example, we can assess the degree with which grizzly bears are negatively associated with roads. Secondly, we may wish to use our models to make predictions about the future distribution, population size and viability of the species given current or potential future habitat conditions. Although ideally a model would serve both purposes, some analysis techniques will serve better for either interpretative or predictive modeling. Two other distinctions will help clarify the modeling strategy used here: the distinction between conceptual and empirical models and between static and dynamic models.

Conceptual Versus Empirical Models

Most existing modeling approaches for carnivores in the Rocky Mountains have evolved out of a site-level planning paradigm. Conceptual models such as Habitat suitability Indices (HSI) and Cumulative Effects Analysis (CEA) are models commonly used by agencies to assess habitat "take" in project-level planning. They are usually based on expert opinion of relationships between habitat and species abundance. These models are an improvement on univariate models in that they offer a method of integrating multiple habitat attributes in an explicit manner (usually the geometric mean). Although based on qualitative review of the literature, HSI models are not always validated with field data. Incorporating variation in habitat relations across the region and exploring the fit between alternate models and empirical data are difficult. Although it is possible to incorporate non-linearities and interactions (e.g., visual cover may only be important near roads), more complex interactions are difficult to model based on expert opinion. The spatial and temporal scale of the model may be unclear. For example, road development may trigger long-term development pressures that are not adequately addressed in the CEA model (Weaver et al. 1986, McLellan 1990). Although useful for project-level analysis, models such as HSI and CEA are probably not sufficient for ecosystem-scale conservation planning (Craighead et al. 1995). In an another approach explicitly designed to address regional-scale questions, the Gap Analysis Program (GAP) uses expert models based primarily on vegetation covertype to evaluate the degree of representation of large assemblages of species in protected areas. However, when evaluating the distribution of habitat for one or a few focal species, especially carnivores species that may have complex spatial dynamics, these types of models may have limited value (Bolger et al. 1997).

Fine-scale conceptual models may also be used to evaluate connectivity. If the analysis does not incorporate the effects of coarser-scale population processes, however, it may fail to identify the most biologically important landscape linkages. We may conceive of patch boundaries and dispersal barriers as membranes or filters (Doak 1995, Wiens et al. 1993). The "rate of flow" or functional connectivity through these areas will depend both on characteristics of the local habitat and on the amount of dispersal "pressure" from adjacent source habitat. If the spatial distribution of source habitat creates pressure for dispersal through already degraded habitat with associated high risk of human-caused mortality, restoration of these areas may be more important to functional connectivity than protection of other more pristine linkages.

The growing popularity of empirical modeling methods such as resource selection functions (Boyce and McDonald 2000) reflects the fact that in many cases, they are more informative and replicable than conceptual models. However, data on species distribution is often not available across the region of interest, and empirical models which perform well in one area may be difficult to generalize to adjacent regions. Therefore, elements of expert judgement must still enter into empirical model development.

Static Versus Dynamic Models

Static spatial statistical models are similar to traditional wildlife habitat models in that they depict species distribution at a single moment in time. However, they incorporate the effects of habitat selection at multiple scales through method such as "moving-window" functions in GIS. Although the effects of landscape pattern (as opposed to landscape composition) can be incorporated through metrics derived from programs such as FRAGSTATS (McGarigal and Marks 1995), usually these static models deal poorly with connectivity.

Dynamic models, such as those used in population viability analyses (PVA), attempt to track the viability of a species over time. Because it is difficult to link spatial data on the distribution of habitat resources to a species' demographic processes, most PVA provide a composite evaluation of viability across a region. However, PVA predictions linked to specific land-management options can provide a powerful tool for conservation planners. Spatially-explicit habitat analysis can identify the most important refugia that have a level of protection sufficient to buffer populations against human-caused mortality. It can also identify optimal locations of buffer zones and corridors that will expand the effective size of core areas by allowing use of semi-developed lands. By evaluating commonalities and differences between potential focal species, this analysis can assess whether one or several species can serve as umbrella species for a larger suite of taxa.

Two major challenges have limited the development of such tools. Because most field data is gathered at finer spatial scales, we lack knowledge of species-habitat relationships and population structure at the regional scale. We also poorly understand how the regional population structure is created by a population's response to habitat variation through its demography and dispersal processes. Application of realistic models to applied regional conservation questions is now becoming possible because of the availability of regional-scale distribution data for focal species and habitat data from sources such as satellite imagery, and the increased ability of computers to process large spatial simulations. Analysis using the actual habitat configuration of regional landscapes allows comparison with validation data from field surveys and evaluation of alternative plausible landscape change scenarios or conservation designs.

Individual-based simulation models retain spatially-explicit information on habitat distribution (DeAngelis and Gross 1992). These models track the fates of many individuals through time as they move across a grid of cells. Each cell can be assigned different levels of habitat quality. The attributes of the cells surrounding an individual interact with movement rules to govern the behavior of the organism. The behavior of large numbers of individuals collectively determine the aggregate characteristics that form the model output.

Individual-based models span a range of complexity, depending on the degree of biological realism and number of demographic parameters they incorporate. One of the simpler applications involves the simulation of dispersal behavior with diffusion models. Individuals disperse from their starting point across a landscape of habitat types with different levels of permeability or dispersal mortality risk. The individuals are "correlated random walkers" (CRW) because their direction of movement is based on a combination of the relative habitat values of the neighboring cells, previous direction of travel, and a random component. Although real organisms use cognitive maps in more complex ways than portrayed in a CRW, these models are useful in mapping the spatial distribution of potential dispersal paths across a landscape. For example, this method has been used to map regional-scale dispersal routes for grizzly bears in the northern Rockies (Boone and Hunter 1996, Walker and Craighead 1997).

Because field data on dispersal is notoriously difficult to gather, many CRW models base movement rules and relative habitat permeability on qualitative rankings. A more promising approach is to derive movement rules from parameters such as turning angle, mean move length and duration that we can estimate for different habitats from field data (Turchin 1991, 1996). A study of marten in the Yellowstone area has used this approach (Foran et al. 1997). Validation of these models may be possible with species such as wolves for which dispersal data are available. The grizzly bear, however, has never been recorded to move between regional subpopulations in the lower 48 states (Weaver et al. 1996), although linkages have been proposed (Picton 1986). Validation of grizzly bear dispersal models may require genetic analysis (Craighead and Vyse 1996).

Spatially-explicit population models (SEPM) are a class of individual-based simulation models that incorporate additional biological realism as habitat-specific demographic parameters. Individuals not only move between cells, but grow, reproduce and die. Model output from SEPMs may include the mean population size, mean time to extinction, or the percentage of suitable habitat occupied. The development of SEPMs has allowed data gathered from intensive demographic studies to be combined with GIS maps of landscape composition and pattern in dynamic models (Murphy and Noon 1992, McKelvey et al. 1993). SEPMs can integrate diverse threats to population viability, including both those, such as demographic stochasticity, that are the concern of the "small-population paradigm," and "declining-population paradigm" factors such as habitat loss (Caughley 1994).

Combining Static and Dynamic Models

Because both static and dynamic models have their strengths and weaknesses, we have sought to combine the two approaches into a unified population viability analysis framework. Complex dynamic models such as SEPMs are often sensitive to errors in poorly-known parameters such as dispersal rate (Ruckelshaus et al. 1997). Although the output of the SEPM must therefore be subject to extensive sensitivity analysis, it provides qualitative insights into factors, such as variance in population size, that are difficult to explore using static spatial models. Conversely, it might be expected that less complex static and non-spatial models may give more robust results when data on species' demography and habitat associations are limited. Static models allow detailed exploration of a species data set for changing temporal patterns and relationships with individual habitat variables. Because we had developed both static and dynamic models for species with varying levels of field data, we were able to compare the results and draw conclusions regarding the role of each type of model in conservation planning.

Our work in the Greater Yellowstone Ecosystem benefits from our data concerning the larger multi-regional context of regional species populations. We are currently completing a companion study, funded by World Wildlife Fund Canada with help from The Nature Conservancy, of carnivore conservation needs in an area stretching from northern Yellowstone to the British Columbia/Yukon border. Our work in the GYE has allowed us to refine these larger conclusions by adding more detailed analysis of species/habitat relations using data not available for the larger US/Canada study area.

Because we model a range of species within the mammalian carnivore guild, our approach is also able to inform more general conclusions as to species response to landscape configuration. Contrasts between the scale of habitat aggregation and that of species distribution may be linked to allometry, variation in home range size (Woodruffe and Ginsberg 1999), dispersal, and demography. Dynamic models permit analysis of both equilibrium behavior (i.e, can current habitat sustain the current species distribution for 200 years?) and transient behavior (e.g., can species such as the wolf recolonize from current refugia or would active reintroduction be necessary?). Analysis of relaxation times, i.e. the time to and pattern of loss of a population after habitat change occurs, allows estimates of the "extinction debt" (Tilman et al. 1994) in the region due to past habitat change. While the dynamic models can help us identify the most demographically important areas within a multi-regional or regional context, more detailed static habitat models can be used to evaluate priorities at finer scales, such as within individual home ranges, and to more accurately predict the effects of fine-scale landscape change. Static model results can be used prospectively (Mehlman 1997) as input to reserve selection analyses such as SITES (Andelman et al. 1999). The dynamic models can also be used to provide input to SITES, but can also be used retrospectively to evaluate focal species viability in portfolios chosen by the SITES model. By evaluating commonalities and contrasts within a group of potential focal species, we can provide guidelines for designing multi-species conservation networks that can retain viable populations of species that differ in both habitat affinity (Carroll et al. 2001a) and demographic characteristics.

CARNIVORE FOCAL SPECIES

Grizzly Bear

The grizzly bear was historically widely distributed from arctic to desert ecosystems of North America and was likely present in varying abundance in most parts of the GYE region. The early establishment of Yellowstone as a national park provided the large core protected area that was key to the survival of the GYE grizzly bear population as the most southerly remnant of the formerly contiguous distribution of the species in the United States. The historical decline of the grizzly was associated with the expansion of livestock grazing, especially of sheep, and associated predator control (Peek et al. 1987, Mattson 1990). Grizzly bears in Yellowstone park itself largely escaped the effects of predator control programs that targeted wolves and mountain lion (Schullery and Whittlesey 1999). A segment of the population became dependent on human-associated food resources at dump sites. The closure of the dump sites in the period 1969-1971 resulted in increased bear mortality as bears left the park or were subject to management control as habituated bears at campgrounds (Craighead et al. 1995). Formation of an interagency grizzly bear recovery program and restoration of non-park habitat through road removal and reduction in grazing has resulted in stabilization or improvement of population status in some areas. At the same time, rapid population growth and development in the GYE, as well as the potential effects of global warming and introduced disease on food plants such as whitebark pine, create an uncertain long-term prognosis for the population.

The grizzly bear has a combination of life history traits that contribute to its low resilience in the face of human encroachment (Bunnell and Tait 1981). The bear's low lifetime reproductive potential (three to four female young per adult female in many regions) makes population viability sensitive to small declines in adult survivorship (Weaver et al. 1996). Subadult males commonly disperse two home range diameters (about 70 km), a distance large enough to escape the protection of most western parks (Weaver et al. 1996). However, successful long-distance dispersal between subpopulations, although common for species such as the wolf, has not been recorded for the grizzly.

Although the grizzly is an omnivore, its resiliency is limited by seasonally high calorie needs (Weaver et al. 1996). The diet of bears in Yellowstone is notable for the absence or scarcity of berries and salmon (Mattson et al. 1991). In other areas, these are the consistent high-quality food sources critical to the buildup of fall fat stores (hyperphagia) (Blanchard and Knight 1991). Whitebark pine (*Pinus albicaulis*) seeds are a critical, although inconsistent, food in autumn (Mattson et al. 1992). Poor years of pine seed production may limit Yellowstone bear populations by increasing movement and associated human-caused mortality (Knight et al. 1988). Ungulate calves and winter-killed carrion are important spring foods. Graminoids and forbs associated with wet meadows and riparian areas are also major components. As Craighead et al. (1995) state, the grizzly bear's habitat needs are "a mosaic of diverse plant communities recurring over an entire ecosystem, not enclaves within them." Landscape and regional-scale factors can be expected to form the coarse-scale constraints within which patch-level resource value becomes important (Mace et al. 1996).

Human-caused mortality comprises 86-91% of adult bear mortality in Yellowstone and Montana (Weaver et al. 1996). The sensitivity of bear populations to small increases in adult female mortality makes even incremental increases in mortality risk or disturbance a threat (Mattson and Reid 1991, Mattson and Craighead 1994). Using an analytical source-sink model, Doak (1995) showed that incremental habitat degradation can have severe nonlinear effects on population viability. Because these threshold effects may take up to a decade to be detected, spatially-explicit modeling of habitat effects may be a more powerful monitoring tool (Mattson and Craighead 1994, Doak 1995).

Roads represent the most important human influence on grizzly habitat. Illegal killing and management control (removal of habituated bears), the two main sources of adult bear mortality in the GYE (Mattson et al. 1987, Weaver et al. 1996), are both associated with roads. The roads' effect may extend up to three km from primary roads and one to 1.5 km from secondary roads (Kasworm and Manley 1990, Mattson and Knight 1991). If these buffer areas represent 32.9% of the GYE, but account for 70.3% of bear mortalities (Mattson and Knight 1991), mortality risk is almost five times higher near roads (Doak 1995).

Recreational development increases bear mortality risk and preempts biologically-productive habitats such as riparian areas. The effect of developments on mortality extends up to six km from the site (Mattson and Knight 1991). Even non-motorized trails may be avoided to a distance of 300 m (Kasworm and Manley 1990, Mace et al. 1996). The impact of recreational development and associated roads reduces the ability of national parks to function as core areas (Gibeau et al. 1996). For example, Yellowstone National Park contains over 800 km of roads and sees more than three million visitors a year (Craighead et al. 1995).

Bears inhabiting the public lands surrounding the parks face additional threats. Shootings by hunters due to misidentification or self-defense remain a major mortality source, and may lower bear survival value in wilderness areas below that in adjacent non-wilderness lands that receive lower hunting pressure (Mace et al. 1999). Logging is the major extractive use of non-park public lands in the region. While the importance of early-seral logged stands for forage production varies by forest type and along regional gradients, the increased road access associated with logging is uniformly negative (Peek et al.1987). Mineral and gas exploration forms another important disturbance source, primarily through associated road development (McLellan and Shackleton 1988, McLellan 1990).

In response to these problems, several tools for evaluating threats to bear habitat have been developed. The primary method agencies have used to model bear habitat value, cumulative effects analysis (CEA) (Weaver et al. 1986), combines three types of effects of humans on bears: direct mortality, habitat alteration, and displacement from habitat. Habitat typing is based on such data as maps of forest timber types, ungulate seasonal ranges, and spawning streams. This modeling approach assigns qualitative scores for each attribute, then sums scores for a composite index of habitat value. The approach is similar to that of the habitat suitability index (HSI) model, but is designed to incorporate changes in habitat effectiveness due to human disturbance in addition to habitat productivity.

Recently, empirical models such as RSFs have been applied to grizzly bear habitat evaluation. Mace et al. (1999) used logistic regression to estimate resource selection functions (Manly et al. 1993) from telemetry data for grizzly bears in the Northern Continental Divide Ecosystem (NCDE). Tasseled-cap greenness, a satellite imagery-derived metric (Crist and Cicone 1984), proved a useful surrogate for food resource availability in their multivariate model, suggesting that even crude metrics such as these may provide a substitute for detailed vegetation data at the landscape scale. Similar models have been developed for the GYE (Boyce and Waller 2000). Merrill et al. (1999) developed a regional-scale habitat model in which habitat productivity and habitat effectiveness values are combined to produce a composite habitat suitability value. Habitat productivity values were created by assigning habitat values to macroscale vegetation types identified with satellite imagery. Habitat effectiveness values were derived from indices of road density and human presence. As an alternative to their conceptual model, Merrill et al. (1999) also developed a multiple logistic regression model combining the two factors. Results of the two models were qualitatively similar, although the empirical model identified somewhat less area as suitable habitat.

Because empirical estimation of bear dispersal rates is difficult, simulation models have been used to evaluate landscape connectivity for bears in the GYE. Boone and Hunter (1996) used a simulation model to predict dispersal routes between grizzly subpopulations in northern Montana and Yellowstone. Walker and Craighead (1997) created a similar model for a larger portion of the Rockies. They assigned cells permeabilities based on vegetation type, length of forest edge, and road density.

Models such as the CEA, which focuses on habitat loss and other direct threats to bears are examples of the "declining population" paradigm (Caughley 1994). An alternate approach, the "small population paradigm" focuses on how chance effects of genetic drift, demographic and environmental stochasticity threaten isolated populations. The GYE bear population, as a high-profile example of such a remnant population, was the subject of the first minimum viable population (MVP) estimate, which was the forerunner of modern PVA analysis (Shaffer 1983). Craighead and Vyse (1996) compared the viability of bear populations on islands of varying size and concluded that while island populations of 100-300 bears have persisted with occasional immigration, isolated populations require at least 1000 bears to persist. Mattson and Reid (1991) found a similar size threshold for viability in European brown bear populations, and placed the Yellowstone population below this threshold. Ideally, "small population" and "declining population" concerns should be unified in a comprehensive analysis.

Gray Wolf

The wolf as a species shows a high level of ecological resilience compared with other large carnivores due to high vagility and favorable life history traits (Weaver et al. 1996). The species' flexible social structure allows pack structure, fecundity, dispersal, and level of intraspecific tolerance to respond as population density shifts with changes in mortality rates and prey abundance (Fritts and Mech 1981, Fuller 1989, Boyd et al. 1995, Weaver et al. 1996). In many areas of the Rocky Mountains, however, wolves were eliminated whereas grizzly bears persisted, suggesting that these compensatory mechanisms have limits. In the rugged landscapes of high elevation or northern mountains, wolves depend primarily on secure valley bottoms for survival. Humans prefer these same areas, which usually results in displacement of wolves. In addition, wolves were targeted by organized predator control programs throughout the GYE region, including within the national parks (Schullery and Whittlesey 1999). Today, organized predator control efforts are more limited, and wolves reintroduced to Yellowstone National Park have rapidly recolonized a large portion of the central GYE. Controversy remains as to the population's future given current levels of mortality, which is chiefly associated with conflicts with livestock on both public and private lands (Gaillard 2001). Nevertheless, the status of wolves in the GYE and central Idaho appears more secure than in other less productive protected areas in the region such as the NCDE and Banff National Park.

Wolves have a high capacity to replace numbers because they reach sexual maturity at an early age and have large litters. Thus, in comparison with grizzly bears, they are able to withstand relatively high levels of mortality. On the other hand, population densities of wolves are usually far lower than population densities of bears occupying the same areas. The wolves occurring in the Rocky Mountains have low population densities and require large home ranges (500-2000 km^2) compared with wolves elsewhere (Paquet 1993, Paquet et al. 1996). In addition, social animals are more susceptible to removal than solitary animals and the large size of pack territories increases mortality risks (Woodruffe and Ginsberg 1999).

Mean dispersal distance for males and females is 148 km, and a dispersal of 840 km has been recorded (Boyd et al. 1995). In expanding populations, many wolves may become dispersers. Genetic threats associated with small populations are of less concern in wolves due to their long-distance dispersal ability (Chepko-Sade et al. 1987, Fritts and Carbyn 1995, Boyd et al. 1995, Forbes and Boyd 1996).

Historically, the primary limiting factor for wolves has not been habitat degradation, but direct persecution through hunting, trapping, and predator control programs. If tolerated by humans, wolves are well equipped biologically to recolonize what remains of their former range. As in the north-central U.S., most of the wolf population in the Rockies will probably be found outside core protected areas (Fritts and Carbyn 1995). Map-based regional conservation planning can help facilitate human-wolf coexistence by identifying areas where human development trends create potential conflicts (Mladenoff et al. 1995, Mladenoff et al. 1997, Massolo and Meriggi 1999).

Generally, wolves locate their home ranges in areas where adequate prey are available, prey accessability is not limited by topography, and human interference is minimized (Mladenoff et al.1995). As with bears, we can divide components of wolf habitat models into biological attributes and human-associated disturbance factors. Even in areas where killing of wolves is generally prohibited, 90% of mortality is human-caused (Pletscher et al. 1997). Wolves generally are not present where the density of roads exceeds 0.58 km/km^2 (Thiel 1985, Fuller 1989). Mech (1989) reported 60% of mortality in a roaded area even after full protection, whereas human-caused mortality was absent in an adjoining region without roads. Although human-caused mortality is consistently cited as a major cause of displacement (Fuller et al. 1992, Mech and

Goyal 1993), wolves may tolerate indirect human disturbance. The record of human/wolf coexistence in southern Europe versus that of wolf extirpation in northern Europe and the U.S. shows that human population density is only one of several factors determining the ability of the two species to coexist (Boitani 1995). As for bears (Mattson et al. 1996), varying lethality of human behavior (i.e., whether guns are carried) is a complicating factor that prevents surrogate measures such as road density from fully explaining wolf distribution. Topographic effects also influence how road densities influence wolves. For example, in mountainous landscapes roads and usable wolf habitats converge in low elevation valley bottoms.

Wolves in Minnesota are now occupying ranges formerly assumed to be marginal because of prohibitive road densities and high human populations (Mech 1993, Mech et al.1995). Legal protection and changing human attitudes are cited as the critical factor in the wolf's ability to use areas that have not been wolf habitat for decades. Nonetheless, wolves in Minnesota continue to avoid populated areas, occurring most often where road density and human population are low (Fuller et al. 1992). Dispersers or marginalized individuals may be pushed into suboptimal habitat as more suitable and safe habitat becomes saturated by dominant animals or packs.
The main factor limiting wolves where they are present and tolerated by humans is adequate prey density (Fuller et al. 1992). Ungulates such as elk (*Cervus elaphus*), deer *(O. virginianus and O. hemionus*), moose (*Alces alces*), and bighorn sheep (*Ovis canadensis*) make up the bulk of the wolf diet (Mech 1970, Fuller 1989), although they may take smaller prey such as snowshoe hares (*Lepus americanus*) and beaver (*Castor canadensis*). In a review of wolf demographics, prey density was shown to explain 72% of the variation in wolf density (Fuller 1989). Although wolves are the most rapidly-reproducing of the large carnivores in the Rocky Mountains, population densities are low in comparison with other carnivore species that use the same range, reflecting the wolf's dependency on ungulate prey species (Keith 1983) that may be limited by the low productivity and rugged topography of the mountainous environment. In the GYE, most ungulate winter range lies outside of core protected areas, with seven of nine elk herds wintering outside the park (Fritts 1990, Fritts and Carbyn 1995).

Logistic regression models similar to RSFs have been used to predict potential wolf distribution in North America and Europe (Mladenoff et al. 1995, 1997, Massolo and Meriggi 1998, Boyce and McDonald 2000). Models have also been developed for the GYE and central Idaho (Houts 2000). The models generally highlight road density as a critical limiting factor, but also have included human population density, ungulate diversity and abundance, and land use. The tasseled-cap greenness index**,** derived from satellite imagery, has proved a successful surrogate for ungulate prey density (Carroll et al. 2001b). Landscape connectivity for wolves has been modeled with "least-cost path" techniques (Paquet et al. 1996) and diffusion models (Walker and Craighead 1997).

Haight et al. (1998) used a simulation model to analyze wolf population dynamics in a semi-developed landscape. They found that low levels of immigration allowed the persistence of isolated wolf populations inhabiting the landscape matrix. Wolves can inhabit areas with high levels of mortality risk if either spatial refugia (protected populations) exist or if dispersal is possible between buffer populations. This suggests that regional planning incorporating core, buffer, and dispersal habitat can increase the effective size of reserves and allow the distribution of wolves to expand to include much of the landscape matrix (Fritts and Carbyn 1995).

Wolverine

Wolverine are well-documented residents of most of the central GYE and are recorded with less certainty from outlying areas such as the Uinta Range. The habitat requirements of the wolverine are relatively unknown compared to those of other carnivores, with current knowledge primarily derived from six field studies (Hornocker and Hash 1981, Gardner 1985, Magoun 1987, Banci 1987, Copeland 1996, and Krebs and Lewis 1999). Because the wolverine diet includes unpredictable resources such as carrion, it has larger home range requirements than equivalent-sized carnivores. Female wolverines mature at three years of age and produce less than one kit per year until death at six to eight years (Copeland 1996). Populations probably cannot sustain annual rates of human-induced mortality greater than seven to eight percent, a rate lower than that usually caused by trapping (Gardner 1985, Banci 1994, Weaver et al. 1996). Areas closed to trapping such as Yellowstone National Park and the Canadian mountain parks appear to have acted as refugia for wolverine (Hatler 1989, Buskirk 1999). Wolverine are not currently listed as threatened or endangered in the United States, but are protected from direct trapping pressure outside of Montana (Banci 1994). Wolverine are still heavily trapped in the Canadian Rocky Mountains, and local distribution there is strongly associated with non-trapped refugia such as parks (Krebs and Lewis 1999). In summary, the wolverine shows a level of demographic vulnerability similar to or greater than the grizzly bear but does not receive comparable protection or conservation focus, in part due to our poor knowledge of its status or habitat needs.

The large home range sizes of Idaho wolverine (a mean of 384 km^2 in females) relative to those in Canada and Alaska suggest more limited food or denning resources (Copeland 1996). Female wolverines must leave their kits for lengthy foraging trips. In the lower 48 states, they often select natal den sites in alpine areas where snow tunnels in talus can provide thermoregulatory benefits for kits and safety from predators (Magoun and Copeland 1998). Potential denning areas have been identified in GIS models (Hart et al. 1997). Regional-scale RSF models (Carroll et al. 2001a, b) have identified human population, road density and snowfall as other factors that may help in predicting wolverine distribution.

Long-range dispersal abilities (> 200 km in Idaho; Copeland 1996) may facilitate wolverine persistence, however, females tend to be philopatric (Banci 1994). Range contraction has been suggested in some parts of the United States (Carroll et al. 2001b) but is difficult to document because sightings of dispersing individuals may continue after the loss of reproductive populations. Most wolverine studies have recorded demographic rates corresponding to sink habitat (Krebs et al. 2000), suggesting that many occupied areas may only be maintained by regional-scale metapopulation dynamics.

Lynx

Because of its recent listing as Threatened under the Endangered Species Act, the lynx has begun to receive greater conservation focus within the United States. Lynx have been documented from most parts of the central GYE and a small population in the northern Wyoming range is the subject of intensive demographic study (Squires et al. 2000). The GYE region lies along the southern periphery of occupied lynx range, although the species was recently reintroduced into Colorado. This marginal location relative to the bulk of the species presents conservation challenges due to unique aspects of the species' habitat needs and demography. The vulnerable status of lynx populations in the southern part of their range (southern Canada and the northern U.S.) is partly due to their obligate association with their major prey, the snowshoe hare. Although they take other small prey such as grouse and squirrels, hares make up the bulk of the diet (Brand et al. 1976). The association of snowshoe hare with specific conifer forest types and seral stages may facilitate modeling of lynx habitat suitability.

Hare populations undergo cyclical fluctuations in the northern part of their range, the extensive boreal forest of northern Canada and Alaska. Populations in the south generally do not show such dramatic cycles, instead remaining at densities typical of the low point of the northern cycle (Koehler and Aubry 1994). This may be due to the fragmented distribution of boreal forest types in the south, and the greater diversity of lagomorph species and hare predators (Wolff 1980). The naturally low density of southern lynx populations makes them more vulnerable to the effects of trapping and forest management (Koehler and Aubry 1994).

The periodic irruptions associated with the high points of cycles in the boreal forest may be important as a source of dispersers for augmenting southern populations (Mech 1980, Koehler and Aubry 1994). During these irruptions, long-distance dispersal of 300-500 km has been recorded (Mech 1977, Brainerd 1985). Lynx form a major part of trapping harvest in Canada (Hatler 1988) and management there may have effects on the number of dispersers in southern areas. While maintenance of regional connectivity is likely to be important, dispersing lynx are often found in atypical habitat, and it is not clear what types of habitat facilitate or block lynx dispersal at this scale. As with the wolverine, favorable local demography may combine with a regional "rescue effect" (Brown and Kodric-Brown 1974) to allow continued occupation of habitat, such as the GYE, which lies at the periphery of the range.

UNGULATE FOCAL SPECIES

Ungulates are the most abundant large mammals influencing the ecosystems of the GYE region. They have historically been the major focus of wildlife management concern in the region but are rarely considered in a regional context encompassing multiple ownerships and states. Ungulate populations suffered severe declines due to intensive market hunting during the late 1800s (Houston 1982), which nearly extirpated species such as bison even within the park itself.

As populations of bison and elk recovered from the market hunting period, they were subject to culling within the park to maintain populations at levels that were lower than historic numbers, although historic population trends are a subject of controversy for the elk. Following the Leopold report (Leopold et al. 1963) and subsequent adoption of the natural regulation policy, elk and bison populations generally increased and expanded in distribution. Despite purchase of additional wintering habitat outside the park, this range expansion has created conflicts due to competition with other land uses and fears of disease transmission to domestic livestock. Ongoing threats to ungulate populations include loss of winter range to development and agriculture as well as overhunting in some areas.

The dynamic model used here (PATCH) is designed for species in which individuals or packs hold an exclusive year-round territory. Most ungulate species are therefore not suited for analysis with the PATCH model. Because ungulate generally exist at higher population densities than carnivores, individual-based models that can mimic area and small population effects may be less necessary. Our approach therefore combines expert-opinion based maps, static RSF models, and analysis of threats due to current and potential future landscape conditions

Several ungulate species, including mountain sheep, moose, and white-tailed deer, have a relatively restricted distribution of wintering habitats within the GYE region. Although more widespread, pronghorn also have critical winter habitat that is limited in extent. The region's pronghorn shows unique genetic diversity (Lee et al. 1994) and concerns over viability exist (Goodman 1996). Critical habitat for these species may be best captured using a fine-filter approach that attempts to protect all critical wintering or parturition areas. Other more specific threats to the species, such as the threat of disease transmission to mountain sheep from domestic sheep, may be addressed by threat analysis of specific areas (i.e., site-level planning).

METHODS

The following sections provide additional detail on the focal species methodology, beyond that supplied in the main text of this report. We used a variety of GIS data on species distribution and habitat characteristics to construct new static models for the region. These results were then compared with those from dynamic models that placed regional population dynamics within a larger multi-regional context.

DATA ON CARNIVORE SPECIES DISTRIBUTIONS

<u>Mesocarnivore Occurrence Data</u>

We used data on sightings, specimens, and trapping records of lynx and wolverine from the Natural Heritage Database programs of the states of Montana, Idaho, and Wyoming (Groves et al. 1995). Records provide the species, date, source of the report, and other details of the occurrence. Using this information, we assigned the records to a scale of reliability similar to that used in previous publications (Aubry and Houston 1992, Maj and Garton 1994). We rated specimens and trapping records as of highest reliability, followed by sightings and tracks grouped according to the expertise of the observer. In addition to problems of reliability or verifiability, the records show spatial sampling bias, for example towards roads, that was addressed by methods described later.

Grizzly Bear Telemetry Data

Grizzly bears in the Greater Yellowstone Ecosystem were one of the first bear populations to be studied using radiotelemetry methods (Craighead et al. 1995). The vertebrate occurrence database for Wyoming (Wyoming Game and Fish Dept., unpublished data) contains over 9000 grizzly bear occurrence records, of which 7388 are telemetry locations (Figure 3). We excluded sightings reports and other non-telemetry locations (blue points in Figure 3) because of their strong tendency to be biased towards roads and tourist facilities. The high level of resources devoted to bear telemetry in the GYE as compared to other bear populations results in relatively complete coverage of the area, although bias towards detection in certain ownerships (e.g., park over national forest) is possible especially in the early data. In order to examine the effects of spatial autocorrelation on model estimates, we also transformed the data set into a grid of bear presence-absence by $1km^2$ cell (similar to Blanchard et al. 1992). In order to examine change over time in grizzly bear/habitat relationships, we divided the telemetry data into that collected before 1980 (n=2315), that collected from 1980 to 1988 (the year of the Yellowstone fires) (n=5304), and that collected from 1989-1992 (n=1888). We also divided the data into early-season (pre-July 15^{th}) (n=3159) and late-season (n=4229) locations.

Wolf Pack Territory Data

We used data on the boundaries of wolf pack territories from fall of 1998 and 2000, as delineated by minimum convex polygons containing reported locations (Ralph Maughan, unpublished data, 1998 data from Houts 2000). Although this type of pack territory data has been used for previous regional-scale analyses (Mladenoff et al. 1995), a more detailed analysis using adaptive kernel estimates would be useful when such data becomes available.

HABITAT DATA

The habitat variables were developed in a GIS format (Table A1). They can be grouped into the five categories of vegetation, satellite imagery metrics, topography, climate, and human-impact related variables. Although acquired at a range of resolutions (Table A1), all variables were generalized to 1 km resolution for the final analysis.

Vegetation Data

Vegetation cover type data was derived from GIS vegetation layers developed from supervised classification of Landsat Thematic Mapper (TM) satellite imagery. Data for Montana, central Idaho, and northwestern Wyoming developed by the Montana GAP program (Redmond et al. 1998) was used as the base classification system. Additional data sets for Utah, southeastern Idaho and western Wyoming developed by the Utah GAP program (Homer et al. 1997) and for central Wyoming and Colorado developed by the GAP programs of those state (Merrill et al.

1996) were crosswalked to the Montana classification system. The minimum mapping unit ranged from 2 ha for Montana to 100 ha for Wyoming. Absolute thematic accuracy for cover type was 61.4% for the Montana data (Redmond et al. 1998). Secondary variables derived from this original vegetation data layer included a binary map of forest types strongly associated with lynx habitat (subalpine fir, Engelmann spruce, and lodgepole pine; Koehler and Aubry 1994). We also derived estimates of seasonal grizzly bear forage value based on coefficients developed from intensive food utilization studies (Mattson 1998).

Satellite Imagery

Although we benefitted from these pre-existing maps of vegetation cover type, other vegetation-related variables such as canopy closure and size class were not available for the entire region. “Pseudo-habitat” variables that are derived directly from unclassified satellite imagery are correlated to varying degrees with ecological factors such as net primary productivity and green phytomass (Cihlar et al. 1991, Merrill et al.1993, White et al. 1997) and have proved useful in modeling wildlife distributions (Mace et al. 1999). Our experience in other regions (Carroll et al. 2001a, 2001b) has confirmed the utility of these variables in carnivore modeling. The “tasseled-cap” indices of brightness, greenness, and wetness (Crist and Cicone 1984) are a standardized means of representing the three principal axes of variation in the values of six TM-equivalent spectral bands. Although metrics such as greenness may be expected to be correlated with abundance of prey species through their relationships to primary productivity, this relationship is weakened by phenological variation between years and spatial variation in percent bare ground and percent dry biomass (Merrill et al. 1993).

Until the launch of the MODIS sensor (Huete et al. 1997) in late 1999, we derived these imagery-based metrics from Landsat TM data. Due to its cost and limited temporal availability, TM data were acquired for a single date in midsummer. The advent of MODIS has made imagery with a similar spectral resolution as Landsat TM available as weekly composites throughout the year. This allows models to incorporate seasonal changes in resource availability and phenology. As of February 2001, MODIS was not yet available for the complete seasonal cycle. We therefore used one midsummer (July19-26, 2000) composite and one composite from early winter (November 8-15, 2000). A better acquisition date for the second composite would have been during snowmelt (March-April), a period when contrasts between summer and winter range are most evident and ungulates migrate in search of new forage (Bjornlie and Garrott 2000). Although MODIS has less spatial resolution than does Landsat TM (250-500m versus 30m), this is outweighed for the purposes of regional modeling by the much larger extent of MODIS scenes, which allows seamless contemporaneous measurements across an entire ecoregion. This study is the first attempt that we are aware of that incorporate such multi-seasonal imagery in wildlife habitat modeling.

Topography and Climate

We derived topographic variables from a digital elevation model assembled at 90 m resolution. Aspect was transformed to derive a metric that varied from zero on exposed southwest aspects to

2.0 on least-exposed northeast aspects (Beers et al. 1966). A topographic complexity variable was derived by combining the values for aspect curvature and slope (ESRI, Inc. 1998). High values of this variable indicate steep or irregular terrain.

We acquired data on mean annual precipitation and snowfall throughout the study area at approximately 2-km resolution (Daly et al. 1994). These climatic data were derived from meteorological records and elevation data by means of the PRISM model (Daly et al. 1994).

Human-Impact Variables

Road density and human population density may serve as surrogates for the effects of humans on wildlife at the regional scale (Mladenoff et al. 1995, Merrill et al. 1999). GIS data on roads, trails, and railroads were assembled for the study area and grouped into classes based on the degree of expected use. Road density calculations, performed at the 1-km resolution, incorporated weights based on this classification, with highways weighted two to three times the weight of unpaved roads. Trails and other routes were rated at 0.35 that of unpaved roads (Merrill et al. 1999). Road data were available at varying scales: 1:24,000 for Forest Service and Park Service lands and 1:100,000 for all ownerships (Figure 4). Seamless predictive models for all ownerships require use of 1:100,000 scale data, but this underestimates road density by up to 40% when compared with 1:24,000 scale data (C. Carroll, unpublished data). Therefore we tested the robustness of species/habitat relationships involving road density by comparing models using both scales of data. Even if not usable in regional modeling, the finer-scale data may be used for post-hoc evaluation of restoration priorities on public lands.

We acquired data on human population at the scale of census blocks. The average area of a census block in this region is 4 km^2 when urban areas are included, but most of the area is contained in blocks over 100 km^2 in size. A data layer representing all population centers as points was interpolated using an inverse distance weighting algorithm (ESRI, Inc. 1998). This provides an approximation of the effects of population centers over distance, for example as they might affect the level of recreational use of adjacent public lands (Merrill et al. 1999). Census data was available for the period 1990-2000.

Other data on potential human-impact factors, such as public-lands grazing (Figure 2), was incorporated in post-hoc evaluation of conservation strategies.

Prey Data

Due to their importance as prey for large carnivores, we included elk winter range and bison range as potential variables in the carnivore models.

STATIC MODELING METHODS

We used multiple logistic regression to compare habitat variables at telemetry or sighting locations with those at random points, or alternatively, random points falling within occupied territories with those points falling outside those areas (Hosmer and Lemeshow 1989). Before building the multivariate models, we conducted exploratory analysis of univariate relationships between potential predictor variables and the occurrence data using generalized additive modeling (Hastie 1993). A large number of random points was used as a comparison set to increase the precision of the estimates for regression coefficients in the multivariate models. The geographic extent of available habitat was the entire region for mesocarnivores and elk, but only the inner GYE region for the grizzly bear and wolf models. Habitat outside the GYE may not be currently available to the recently-reintroduced wolf or the dispersal-limited grizzly bear.

A large set of alternate multivariate models was constructed and evaluated with the Bayesian Information Criterion (BIC), a diagnostic statistic that penalize for overfitting (Schwarz 1978). We also considered interpretability and field knowledge of the species when choosing among competing models that had similar BIC values. Models were not allowed to contain more than one of a pair of highly correlated variables. Because many candidate models were considered, the multiple regression analysis should be considered exploratory. Predicted habitat values can be seen as map-based hypotheses subject to refinement and validation by future survey data (Murphy and Noon 1992, Carroll et al. 1999).

The spatial correlation structure of wildlife distribution data can be modeled as a combination of coarse-scale trend and mesoscale variation (Bailey and Gatrell 1995). Although we did not incorporate trend surface variables derived from geographic coordinates directly into our models, the significance of coarse-scale factors, particularly precipitation, is probably partially due to trend surface effects. We modeled mesoscale environmental covariates with a moving-average function that assigns to each cell the mean value of the attributes within a surrounding circular window.

We used the coefficients from the final model to calculate a resource selection function (RSF) $w(x)$ for used (occurrences) and available (random) resources (Manly et al. 1993, Boyce and McDonald 1999).

DYNAMIC MODELING METHODS

We performed population viability analyses using the program PATCH (Schumaker 1998). PATCH links the survival and fecundity of individual animals to the GIS data on mortality risk and habitat productivity measured at the location of the individual or pack territory. The model tracks the demographics of the population through time as individuals are born, disperse and die, predicting population size, time to extinction, and migration and recolonization rates.

PATCH is a females-only model designed for studying territorial vertebrates. It uses a life history simulator based on a population projection matrix (Caswell 2000). The model year begins with the survival and breeding decisions. Next comes the optional movements of adult animals and the mandatory dispersal of the juveniles. Finally a census is taken. No additional mortality is associated with the movement processes. The simulations incorporate demographic stochasticity using a random number generator. We incorporated environmental stochasticity by allowing mortality and fecundity rates to vary from year to year with a variance based on published data (e.g, Mills et al. 1996, Pease and Mattson 1999, Mattson 2000) .

PATCH ignores intra- and inter-species interactions and focuses instead on the ability of a landscape to promote or preclude population persistence. Territories are allocated by intersecting the GIS data with an array of hexagonal cells. The GIS maps are assigned weights based on the relative levels of fecundity and survival rates expected in the various habitat classes. A hexagon's score is computed as the arithmetic average of the habitat weights associated with each of the data pixels contained within it. Survival and reproductive rates are then supplied to the model as a population projection matrix. The model scales the matrix values based on the hexagon scores, with lower scores translating into higher mortality rates and lower reproductive output.

Adult organisms are classified as either territorial or floaters. The movement of territorial individuals is governed by a site fidelity parameter, but floaters must always search for available breeding sites. The movement routines available include selection of the best available site within a search radius and selection of the closest available site within a search radius. Most simulations in this analysis used a third option, the directed random walk. Movement decisions in a directed random walk combine varying proportions of randomness, correlation (tendency to continue in the direction of the last step), and attraction to higher quality habitat, but without knowledge of habitat quality beyond the immediately adjacent territories.

The model produces tabular outputs such as population size as a function of time and extinction probability. It also records spatial data such as the occupancy rates of each breeding site present in the landscape, which can then be compared with density estimates gathered in the field. The model computes expected source-sink behavior for each hexagon based on its score and on the vital rates supplied by the user. Observed source-sink behavior is tracked during a simulation as the difference between a hexagon's emigration and immigration rates.

PATCH's simplified life history module, when coupled to spatial pattern through GIS data, may produce complex model behavior. Individuals compete for high quality breeding sites, which introduces density dependence, source-sink behavior, and, frequently, metapopulation-like dynamics. The model allows the landscape to change through time. This permits the user to quantify the consequences of landscape change for population viability, examine changes in vital rates and occupancy patterns that might result from habitat loss or fragmentation, and identify source and sink habitats within a landscape.

Dynamic viability modeling for the various carnivore focal species began with development of the GIS data on habitat suitability (Carroll et al. 2001a and previous section). Two types of models were used to approximate habitat suitability, depending on the data available on demography and distribution. The analysis for large carnivores such as the grizzly bear and gray wolf benefits from a greater volume of field data on habitat use and demography. Because these species are difficult to survey, however, we lack readily available data on their distribution at the scale necessary for development of multi-ecoregional models encompassing both the GYE and the larger Rocky Mountain region. We therefore used regional-scale conceptual models to produce the PATCH input maps for these species. Although we have not tested how scaling up to the regional level affects the significance and coefficients of the habitat variables, the calibration of the habitat maps to demographic data allows some verification of their regional-scale explanatory power. PATCH predictions using this framework have been validated with an independent grizzly bear survey data set from British Columbia (Mowat and Strobeck 2000).

Smaller species such as the wolverine and lynx are more poorly-known as to demography and habitat use, but have readily-available regional data on their distribution, in the form of sighting or trapping locations (Carroll et al. 2001a). For these species, we developed resource selection functions (RSFs) as described above. Because the PATCH analysis placed the GYE region within a multi-regional context, RSF models developed for the larger Rocky Mountains region rather than the GYE itself were used as input. Because RSFs are derived directly from regional-scale data, they make fewer assumptions than do the conceptual models as to the scaling up of field data on habitat selection. Consequently, they are also more difficult to link to field estimates of survival and fecundity.

Earlier versions of the PATCH model (Schumaker 1998) used the same GIS data layer to quantify both survival and fecundity. Survival in carnivores is often linked to factors such as human settlement that may vary independently (or often inversely) from the habitat productivity factors that predict fecundity. Therefore, we adapted the model to allow fecundity and survival to be derived from separate GIS data layers. For the grizzly bear and gray wolf, these were derived from separate conceptual models. For large carnivores, availability of fecundity and survival estimates from a range of telemetry study areas allows calibration of GIS data to demography parameters.

For the forest carnivores, the RSF models predict distribution, which is a composite result of survival and fecundity in different habitats. Therefore, separating the RSF results to produce two grids is more difficult. Empirical models ideally could be developed from extensive field data on fecundity and distribution, but such data would be extremely difficult to acquire for species such as the wolverine. Although the link from RSFs to fecundity and survival must therefore be made based on species knowledge, we believe that for these poorly known species, RSF-based estimates are still superior to those from conceptual models.

General Structure of Dynamic Models

The PATCH model requires inputs in the form of a demographic matrix and parameters estimating territory size, dispersal distance, search behavior, and site fidelity (Table A2). Territory size in the PATCH model includes interstitial areas, and therefore is generally larger than average pack territory size as measured by a home range estimator for radiotelemetry data. Dispersal distance in PATCH does not show the long-tailed distribution seen in most carnivore populations, so maximum dispersal distance should be set as more similar to mean dispersal distance in PATCH than in real populations. The demographic parameters (Table A2) used in the PATCH Leslie matrix represent rates from optimal habitat. Because PATCH scales demographic rates to habitat quality, most territories will have survival and fecundity rates much lower than those shown here. Fecundity is reported as females per adult female, or per pack in the wolf.

One thousand simulations were performed for each model scenario to quantify stochastic variability in the outcomes. Our mapped simulation results are equilibrium predictions, in that current predictions depict the current "carrying capacity", or the capacity for an area to support a carnivore species over 200 years. Therefore areas such as central Idaho will exhibit current capacity to support the extirpated grizzly bear, and some rapidly developing areas will show no long-term ability to support their current complement of species. Besides adding separate data layers for fecundity and survival, we modified PATCH by allowing territory holders to be social rather than solitary. As applied in the case of the wolf, young animals can either remain on a natal territory or disperse based on size of their natal pack. This adds demographic resilience as individuals from the same pack can be quickly replace territory holders (alpha females) that die. The social structure also modifies the rate and pattern of dispersal and colonization.

The landscape change scenarios used in this initial analysis were simplified estimates of potential change in human-associated impact factors (e.g., roads and population) during the period 2000-2025. They did not include vegetation change except indirectly in the case of the lynx. Census data were available for the period 1990-2000. We predicted human population growth from 2000 to 2025 based on growth rates from 1990 to 2000, but adjusted predicted 2025 population to match state-level Census Bureau predictions based on more complex socioeconomic models. Road density was predicted to grow at 1% per year. The one study we area aware of that documents change in road density in a similar Rocky Mountain landscape in Colorado (Theobald et al. 1996) found increases of about 2% per year.

The landscape scenarios evaluated included:

1) Current conditions
2) Human population as of 2025, increased road development on private and non-protected public lands
3) Human population as of 2025, increased road development on private lands only.

Lynx population dynamics in boreal habitat have been found to be closely linked to cyclic change in habitat quality as related to snowshoe hare density and other factors such as climate (Stenseth et al. 1999; Mowat et al. 2000). The degree of population cycling at southern range limit is poorly known. We incorporated several cyclic habitat change scenarios into the lynx model by scaling the RSF-based habitat quality values to lynx demographic performance at different points in the cycle (e.g. Slough & Mowat 1996). For the other species, habitat change does not show as a clear cyclic pattern. Data on expected changes in habitat productivity would need to be derived from predictive forest growth models or probabilistic landscape transition matrices. This is a future research area, but outside the scope of the current study.

Because of the sensitivity of the PATCH results to uncertainty in estimating poorly known parameters, we evaluated change in predictions due to variation in:

1) GIS data on habitat attributes
2) Demographic rates attributed to varying levels of the habitat attributes
3) Structure of the Leslie matrix
4) Mean territory size
5) Site fidelity
6) Search (dispersal) behavior
7) Maximum dispersal distance
8) Initial population size
9) Effects of environmental stochasticity.

SPECIES-SPECIFIC MODELS

Grizzly Bear

We could establish a strong link between the GIS habitat data and demographic parameters because a large volume of published field studies with estimates of fecundity and survival are available (e.g. Craighead et al. 1974; Knight & Eberhardt 1985; Hovey and McLellan 1996; Mace & Waller 1998; Pease & Mattson 1999; Herrero et al. 2000, Mattson 2000). Conceptual models were used to estimate relative fecundity and survival. The fecundity model was based on tasseled-cap greenness (Mace et al. 1999), whereas a metric combining road density, local human population density, and interpolated human population density (Merrill et al. 1999) predicted mortality risk. Survival was also proportionately increased in parks due to lack of hunting and consequent lower lethality of humans. Because most field studies are located in protected areas, bear mortality in multiple-use landscapes is poorly quantified (but see Mace & Waller 1998). Therefore, the sensitivity analysis compared high and low mortality scenarios with differing rates of increase in mortality with increases in human impact (e.g., road density). In the high mortality scenario, survival in habitat with moderate road density was 90% of that under the low mortality scenario.

Gray Wolf

The habitat variables for the wolf model were similar to those used for the grizzly bear, with the exception that the fecundity layer incorporated the negative effect of terrain (slope) on prey availability (Carroll et al. 2001b). Field estimates of fecundity and survival were also extensive for this species (e.g. Ballard et al. 1987; Fuller 1989; Hayes & Harestad 2000). In addition to differences in habitat affinities, the social structure incorporated in the wolf model caused results to differ from those of the grizzly bear simulations.

Wolverine

Very little is known about wolverine fecundity and mortality rates (but see Banci 1994; Copeland 1996; and Krebs & Lewis 1999), much less their correlation with habitat factors. We used a RSF we had previously developed from sightings data for the U.S. Rocky Mountains (Carroll et al. 2001a). The variables in the RSF include cirque denning habitat, road density, interpolated human population density, precipitation and tasseled-cap wetness. The first three of these variables are most plausibly linked to survival rates, of either kits (denning habitat [Magoun & Copeland 1999]) or adults (road and human population density [Krebs & Lewis 1999]). This linkage of habitat to demography may not be robust due to the scarcity of field knowledge. Given the assumption that the RSF value is linked to survival, however, we can predict the effects of future landscape change by substituting expected future values of human population density and road density into the RSF and simulating future population dynamics. The dispersal distance used here, five home range diameters or 92 km, reflects the observation that long-distance dispersal is less common in female than in male wolverine (Banci 1994). Given the relative isolation of the GYE wolverine population, we used the PATCH model to address the question of whether this population is viable in isolation.

Lynx

In this species we also used a RSF model developed for the larger Rocky Mountain region (Figure 12) that incorporated tasseled-cap brightness and greenness, latitude-adjusted elevation, and topographic complexity. For this species, RSF values are plausibly linked to both fecundity and survival. Both these parameters vary cyclically in the lynx as they track changing habitat condition (Mowat et al. 2000). Thus, the lynx model helps explore the effects of prey cycling on peripheral populations such as are found in the southern portion of the species' range.

We initially derived estimates of relative survival and fecundity across the lynx population cycle from estimates made in boreal habitats (Slough & Mowat 1996; Mowat et al. 2000). Because lynx populations in the southern portion of their range may show lower variance in demographic rates than in northern areas (Koehler & Aubry 1994; Aubry et al. 2000), we performed simulations with two parameter sets whose variance was somewhat or greatly reduced from that in boreal populations. For this species, we also compared viability of an isolated regional lynx population with viability of one connected to boreal populations.

Elk

We assembled data on elk wintering habitat from several sources, primarily state game agencies. Winter range was evaluated as to current management status, threat and potential level of human impact. Logistic regression which compared areas classified as winter habitat in the above data with areas not considered winter habitat was used to construct a predictive model of potential winter habitat.

Multi-Species Prioritization

Data layers from the RSF models were incorporated as additional targets in the SITES reserve selection analysis. For grizzly bear, wolf, wolverine and lynx, we set a target of habitat sufficient to support 75% of current potential population, as defined by the output of the RSF analysis (Boyce and McDonald 2000). We compared SITES solutions which included focal species with results from the PATCH model to assess whether SITES solutions adequately insured population viability and if not, what additional areas were suggested by the PATCH model. Two types of comparisons were used:

1) Areas selected in the SITES model were prioritized as to their irreplaceability and vulnerability in the PATCH output by overlaying megasite boundaries on the PATCH results. Irreplaceability in this context is the value of an area as source habitat. Vulnerability is measured as the predicted decline in demographic value (lambda) over the next 25 years. Areas identified in this step might include sink habitat that is of only moderate RSF value but protection of which would greatly enhance population viability by reducing mortality rates of animals dispersing from adjacent high-quality habitat. Dynamic model results also contributed one of the nine criteria making up the overall megasite irreplaceability scores. PATCH irreplaceability in the composite scores was an average of lambda values for grizzly bear, wolf, and wolverine, weighted by the likelihood that a site was occupied by the species.

2) We also ran the PATCH model on landscape which included additional protection and restoration of sites in the selected portfolio to more accurately assess the effects of the portfolio on species viability. The dynamic model also provided qualitative insights on appropriate management guidelines that are only evident when we combine information on habitat requirements with that on demography and dispersal.

Table B1. Data layers evaluated in the development of the static habitat models.

Data Layer	Resolution	Reference
Vegetation-derived variables		
Lynx cover types	30 m	Koehler & Aubry 1994
Grizzly Bear forage value - seasonal		Mattson et al. 1998
Grizzly Bear forage value - annual		"
Other biological data		
Elk winter range		
Bison range		
Satellite imagery metrics (MODIS)		
Brightness - July	30 m	Crist and Cicone 1984
Greenness - July	30 m	"
Wetness - July	30 m	"
Brightness - November	30 m	"
Greenness - November	30 m	"
Wetness - November	30 m	"
Topographic variables		
Elevation	90m	
Slope	90m	
Transformed Aspect	90m	
Topographic complexity	90m	
Cirque denning habitat	90m	Hart et al. 1997
Climatic variables		
Average annual precipitation	2 km	Daly et al. 1994
Average annual snowfall	2 km	Daly et al. 1994
Human-impact associated variables		
Human population density	2 km	
Interpolated human population density	1:100,000	Merrill et al. 1999
Road and trail density	1:24,000	
Road and trail density	1:100,000	
Management status	1:100,000	

Table B2. Parameters used in the PATCH simulations

SPECIES: PARAMETER	GRIZZLY BEAR	WOLF	WOLVERINE	LYNX	FISHER
Territory size (km^2)	270	504	270	90	36
Site fidelity	High	High	High	Medium	High
Dispersal behavior	DRW*	DRW	DRW	DRW	DRW
Maximum dispersal distance (km)	56	254	92	268	54
Maximum Survival Rates					
Young - year 0	0.82-0.85	0.44	0.74	0.78	0.56-0.70
Subadult - year 1	0.89-0.92	0.83	0.95	0.78	0.70-0.80
Adult - year 2+ - range	0.93-0.97	0.94	0.95	0.99	0.75-0.85
At senescence (at year in [])	n/a	0.44-0.67[5]	0.74-0.84[8]	0.44-0.67[8]	0.30-0.70[6]
Maximum Fecundity Rates					
Subadult Year 1	0	0	0.23	2.40	0.75
Adult Year 2	0	2.20	0.36	2.70	1.2
Adult Year 3+	0.48-0.53	3.10	0.36	2.20-2.90	1.2

* DRW - directed random walk

Table B3. Coefficients of grizzly bear RSF models

MODEL	BRIGHT-JULY	GREEN-JULY	BRIGHT-NOV	GREEN-NOV	WET-NOV	SLOPE	ELK WINTER
FULL	-0.1195554	0.2036079	0.0018805	0.0621955	-0.1790409	0.0312992	0.5878537
SPRING	-0.0618334	0.1704201	0.0048197	0.0721794	-0.1350184	0.0315513	1.0559450
FALL	-0.0996912	0.2090403	0.0020677	0.0418824	-0.1673504	0.0380699	0.2378139
GRIDDED	-0.0389692	0.2117586	-0.0002050	0.0009162	-0.1088770	0.0239882	0.3925391
PRE-1980	-0.0809886	0.1581564	-0.0066997	-0.0039182	-0.1728311	0.0033935	-0.0044247
1980-1988	-0.0722847	0.2339847	-0.0045728	0.0294628	-0.1989261	0.0614326	1.0238270
1989-1992	-0.0994206	0.2617057	0.0086235	0.0382245	-0.0944548	0.0406895	0.1366633

MODEL	ROAD	PUBLIC	WILD	PARK	RDxPUBLIC	RDxWILD	RDxPARK	BRTxWET
FULL	-0.2770475	2.3507430	4.7203960	6.4744460	-0.3633616	-3.1425000	0.4578810	0.0014194
SPRING	-0.3799387	2.9477720	4.5489350	6.6324620	-1.5061570	-2.6506550	0.4573853	0.0008367
FALL	-0.4589207	2.3329800	4.6273620	6.1478220	0.1535016	-2.5573240	0.8071783	0.0012872
GRIDDED	-0.1299088	2.7071680	4.5512350	5.8898770	-0.4249298	-2.4215540	0.1262847	0.0008644
PRE-1980	-0.2176987	2.8719960	4.9259340	7.2886950	-0.0001205	-1.3462280	-0.4361241	0.0013593
1980-1988	-0.5531019	1.9274110	3.7885870	5.6127590	-0.5122449	-2.5981940	1.5348530	0.0017055
1989-1992	-0.2026080	2.4962840	5.2853710	4.9545420	0.0293610	-6.8325360	0.9832976	0.0010690

Table B4. Coefficients in wolf RSF model

July brightness	-0.0439367
July greenness	0.2297324
July wetness	-0.0865327
November wetness	-0.0500398
Elk winter range	0.9335477
Annual snowfall	0.0025469
Annual snowfall quadratic	$-3.271597*10^{-7}$
Slope	0.2380835
Slope quadratic	-0.0103991
Road density	-0.2000215
Management - general public	-0.0069822
Management - Wilderness	0.8664791
Management - Park	2.410845

Table B5. Coefficients in wolverine RSF model

<u>Montana/Idaho</u>

July wetness	-0.0500331
Annual snowfall	0.0016946
Annual snowfall quadratic	$-1.921311*10^{-7}$
Elevation (latitude-adjusted)	-0.0007151
Interpolated human population	-0.0012279
High road density threshold	-0.4226387

<u>GYE/UWRM</u>

July wetness	0.0054830
Elevation (latitude-adjusted)	0.0176733
Elevation quadratic	$-2.756892*10^{-6}$
Annual precipitation	0.0100790
Annual precipitation quadratic	$-4.31784*10^{-6}$
Management - general public	0.1893558
Management - wilderness	0.9611491
Management - park	1.705577

Table B6. Coefficients in lynx RSF models

Montana/Idaho

July brightness	-0.08150694
July greenness	0.06422866
Elevation (latitude-adjusted)	0.0007370107
Topographic complexity	-0.04226518
Low road density threshold	-2.386417

GYE/UWRM

July brightness	-0.03028083
July greenness	0.08856437
Lynx covertypes	1.475028
Elevation (latitude-adjusted)	0.02013584
Elevation quadratic	$-3.068737*10^{-6}$
Management - general public	1.332069
Management - wilderness	2.009744
Management - park	2.114411
Low road density threshold	-3.114132

Table B7. Coefficients in elk winter habitat predictive model

November brightness	-0.0015311
November greenness	0.0093979
November wetness	-0.0040159
Transformed aspect	-0.5528999
Slope	0.4258639
Slope quadratic	-0.0099077
Topographic complexity	-0.0438973
Annual snowfall	0.0011134
Snowfall quadratic	-4.129575*10-7
Annual precipitation	0.0093349
Precipitation quadratic	-9.730421*10-6

Appendix C: Aquatic Classification

The aquatic classification was done by Mary Lammert of TNCs Freshwater Initiative. We used two levels of aquatic habitat classification: 1) aquatic macrohabitats, identified at the stream reach level; and 2) aquatic ecological systems, identified at the watershed to basin level. Both aquatic habitat classifications utilize four components: 1) stream size (headwater to large river; 2) elevation (low to alpine); 3) stream gradient (low to very steep); and dominant geology (coarse, porous, nonporous). Aquatic macrohabitats are classified by specific portions of the range of each of the four components, while aquatic ecological systems, being aggregations of macrohabitats, represent a greater range of component gradients.

Aquatic Macrohabitat Classification

Size:

Size	Link
1Headwater	1–30
2Creek	31-75
3Small River	76-500
4Large River	>500

Elevation:

Elevation Class	Meters above sea level
1Low	<915
2Foothills	915-1830
3Montane	1830-2745
4Alpine	>2745

Gradient:

Gradient class	Gradient (m/m)
1Low	<.02
2Moderate	.02-.04
3Steep	.04-.10
4Very steep	>.10

Dominant Geology in catchment:

Dominant Geology class	Texture	Chemistry	Flow characteristics
CN	Coarse	Neutral/acidic	Stable flow
PN	Porous	Neutral/acidic	Moderately stable flow
PC	Porous	Carbonate	Moderately stable flow
NN	Non-porous	Neutral/acidic	Unstable flow

Rules for determining dominant geology

All of the geologies were summarized into four classes:
Coarse
Porous – Neutral to acidic
Porous – carbonate
Nonporous – neutral to acidic

Dominant geology
>50% of the total area contributing area.

Co-dominants were those that were 30% or more in two classes

The dominant/co-dominant combinations were then used to group the reaches into four likely hydrologic regime categories.

1	CN	highest groundwater potential
2	PN, PC, CN + PN, CN+PC	moderate groundwater potential
3	CN+NN, PN+NN	low groundwater potential
4	NN, PC+NN	all surface

The macrohabitat classes are combinations of the four variables in the following order
Size
Dominant Geology (hydrologic interpretation)
Elevation
Gradient

For example:

Class 1234 is

headwater stream, moderate groundwater potential, montane elevation, very steep gradient.

Aquatic Ecological Systems Components Classification

Size:

Size	If many intermittents (order)	If few intermittents (order)	System code
1Headwater	1–2	1	1
2Creek	3-4	2-3	1
3Small River	5	4	2
4Large River	6	5+	3

Elevation:

Elevation Class	Meters above sea level	System code
1Low	<915	4
2Foothills	915-1830	4
3Montane	1830-2745	3
Montane and alpine	>1830	2
4Alpine	>2745	1

Gradient:

Gradient class	Gradient (m/m)
1Low	<.02
2Moderate	.02-.04
3Steep	.04-.10
4Very steep	>.10

Systems codes: if all stream steep or very steep – then 1
If range includes moderate and low then 2

Dominant Geology:

Granite/volcanic	1
Sedimentary	2
Alluvial or glacial	3

The aquatic ecological system classes are combinations of the four variables in the following order
Elevation
Gradient

Size
Dominant Geology (hydrologic interpretation)

system code	system description
1211	alpine, includes moderate and low gradients, headwater and creek, granitic or volcanic
1213	alpine, includes moderate and low gradients, headwater and creek, alluvial or glacial basin
2111	alpine to montane, steep and very steep, headwater and creek, granitic or volcanic
2112	alpine to montane, steep and very steep, headwater and creek, sedimentary
2113	alpine to montane, steep and very steep, headwater and creek, alluvial or glacial basin
2211	alpine to montane, includes moderate and low gradients, headwater and creek, granitic or volcanic
2212	alpine to montane, includes moderate and low gradients, headwater and creek, sedimentary
2213	alpine to montane, includes moderate and low gradients, headwater and creek, alluvial or glacial basin
3111	montane, steep and very steep, headwater and creek, granitic or volcanic
3112	montane, steep and very steep, headwater and creek, sedimentary
3211	montane, includes moderate and low gradients, headwater and creek, granitic or volcanic
3212	montane, includes moderate and low gradients, headwater and creek, sedimentary
3213	montane, includes moderate and low gradients, headwater and creek, alluvial or glacial basin
3221	montane, includes moderate and low gradients, small river, granitic or volcanic
3222	montane, includes moderate and low gradients, small river, sedimentary
3223	montane, includes moderate and low gradients, small river, alluvial or glacial basin
3232	montane, includes moderate and low gradients, large river, sedimentary
3233	montane, includes moderate and low gradients, large river, alluvial or glacial basin
4112	foothill to montane, steep and very steep, headwater and creek, sedimentary
4211	foothill to montane, includes moderate and low gradients, headwater and creek, granitic or volcanic
4212	foothill to montane, includes moderate and low gradients, headwater and creek, sedimentary
4213	foothill to montane, includes moderate and low gradients, headwater and creek, alluvial or glacial basin
4221	foothill to montane, includes moderate and low gradients, small river, granitic or volcanic

system code	system description
4222	foothill to montane, includes moderate and low gradients, small river, sedimentary
4223	foothill to montane, includes moderate and low gradients, small river, alluvial or glacial basin
4231	foothill to montane, includes moderate and low gradients, large river, granitic or volcanic
4232	foothill to montane, includes moderate and low gradients, large river, sedimentary
4233	foothill to montane, includes moderate and low gradients, large river, alluvial or glacial basin
9999	artificial channel
12121	alpine, includes moderate and low gradients, headwater and creek, sedimentary, lake connected
21111	alpine to montane, steep and very steep, headwater and creek, granitic or volcanic, lake connected
22111	alpine to montane, includes moderate and low gradients, headwater and creek, granitic or volcanic, lake connected
32111	montane, includes moderate and low gradients, headwater and creek, granitic or volcanic, lake connected
32121	montane, includes moderate and low gradients, headwater and creek, sedimentary, lake connected
32131	montane, includes moderate and low gradients, headwater and creek, alluvial or glacial basin, lake connected
32231	montane, includes moderate and low gradients, small river, alluvial or glacial basin, lake connected

TNC GIS Tools for Aquatic Macrohabitat Classification

Overview for version distributed April 2000

These tools are for use with EPA RF3 hydrographic data, although some of the tools will work or can be modified to work with other datasets. These tools are distributed with no guarantee of accuracy or effectiveness. Known problems with the tools are described in the individual documentation files, but output from the tools should always be checked for accuracy.

The ARC/INFO Tools and Visual Basic Tools are the tools currently being used by TNC's Freshwater Initiative for macrohabitat classification. The 4 Arcview extensions may also be of use for doing this type of classification work, so they are also included.

Time required to run these tools varies depending on the size of the area involved and the number of attributes to be generated. Based on recent work running the tools for 70 USGS catalog units in the Southeastern U.S., a best guess is that once the data are prepared, it would take someone who is unfamiliar with the tools 1-2 weeks to generate all the major stream classification attributes for a similar-sized area. This work was done on a Pentium 600 Mhz CPU. Major stream classification attributes are gradient, connectivity classes, order, link, downstream link, arbolate sum, and contributing area. The most time-consuming task is running the Visual Basic script, which is required in order to calculate stream orders, links numbers, and contributing area, and fixing erroneous codes in the RF3 which prevent that script from running properly.

For those unfamiliar with RF3 data, documentation is available on EPA's webpage, at: http://www.epa.gov/owowwtr1/monitoring/rf/techref.html

Description of Files

TNC ARC/INFO tools:

A collection of AML's that extract stream and lake parameters, including stream upstream and downstream connectivity classes, number of connected intermittent and perennial streams, elevation, and gradient; and lake elevation, geology, subsection, and number of surface connections.

In AMLs directory
Amlguide.doc: Documentation on using the AMLs.
Streamrun.aml, Flip.aml, Upconn.aml, Downconn.aml, Attribstr.aml: AMLs for extracting stream parameters.
Lakerun.aml, Elev3.aml, Lknet.aml: AMLs for extracting lake parameters

Visual Basic Tools for Hydrologic Analysis:

A Microsoft Access database containing Visual Basic scripts and queries that calculate Strahler stream order, stream link (number of first-order reaches upstream of current reach), downstream link, contributing area (total and by land-cover type), and arbolate sum (stream length upstream of current reach) using all and intermittent upstream reaches.

<u>In MS Access – VB directory</u>

Vbtools.mdb: Sample Microsoft Access database with Visual Basic tools and queries for stream attribution and flow routing analysis using RF3 data.
VB_tools.doc: Documentation for Vbtools.mdb.

<u>Custom ArcView Delineation Tools:</u>

An Arcview extension with tools for editing shapefiles. Includes tools for stream attribution using polygon layers, calculation of stream gradient, manual attribution of streams and lakes, and splitting and merging of arc segments.

WARNING: Splitting of RF3 arcs can cause serious problems when the data are used with other GIS tools So, before using any of these delineation tools, make a backup copy of your coverage to insure that arc-splitting does not cause problems.

In Arcview delineation tools directory
Tnc_ext.avx: Arcview extension containing TNC delineation tools.
Tools.doc: Documentation on using TNC delineation tools.
Riverlk.ctl: Control file for TNC delineation tools.

TNC macrohabitat attribute tool extension:

An Arcview extension for storing macrohabitat information for user-selected reaches.

In Arcview macrohabitat tool directory
Addhabcode.avx: Arcview extension.
Addhabcode.doc: Documentation for macrohabitat tool.

<u>Other tools:</u>

The two directories below contain two Arcview extensions that are not specific to aquatic habitat classification, so no documentation is provided.

<u>TNCtools directory</u>

TNCtools.avx: Arcview extension containing ESRI sample scripts.

Xtools directory
XtoolsMH.avx: Arcview extension containing tools for overlay analysis.

Contact Information

TNC's macrohabitat classification methodology and GIS tools are currently evolving and are open to improvement. The tools available on the website will be updated, so check back periodically. Tool updates will be announced through TNC's GIS listserv. The tools may eventually be adapted for use with the National Hydrography Dataset, to be distributed by USGS/EPA.

Questions or comments on these tools can be directed to:

Tom FitzHugh
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The Nature Conservancy, 8 S. Michigan Ave., Suite 2301, Chicago, IL 60603
phone: 312-759-8017; fax 312-759-8409
email: tfitzhugh@tnc.org
www.freshwaters.org

Appendix D: Megasite Descriptions

Megasite Quick Reference

Bear River
Bear River Range
Bighorn Canyon
Blackfoot-Salt
Boulder-Stillwater
Buffalo Fork
Clark Fork
Cottonwood Creek
Crazy Woman
East Uintas
Gannett Hills
Grey's River
Greybull
Henry's Fork
Hoback
Logan
Portneuf
Provo River
Reservation
Rock Creek
South Bighorns
South Caribou Mountains-Gray's Lake
South Fork Snake
South Uintas
South Wasatch
South Winds
South Wyoming Range
Spanish Peak Additions
Upper Bear
Upper Clark Fork
Upper Gallatin
Upper Green
Upper Gros Ventre
Upper Shoshone
Upper Tongue
Upper Wind
Upper Yellowstone-East Gallatin
Wasatch Front
Weber-Lost Creek
West Bighorn
West Slope Teton
West Yellowstone
Wood River

Above Stockton Creek. (C)George Wuerthner

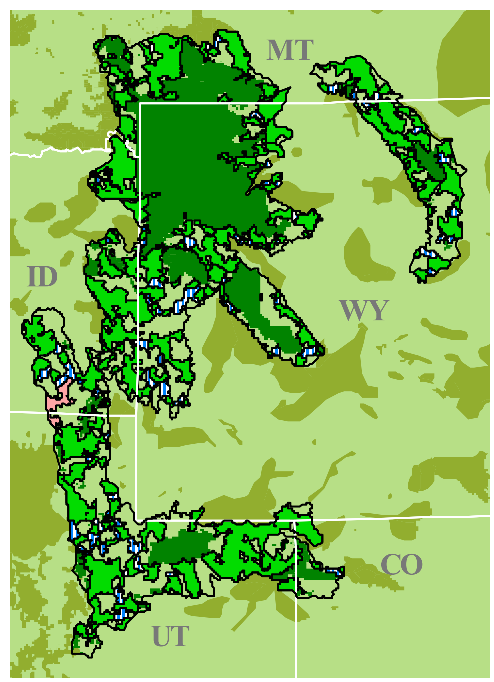
Site Name: Bear River
Size: 156,986 acres
Quadrant: 4
Irreplaceability Score: 30.3
Vulnerability Score: 31.3
Combined Score: 61.6

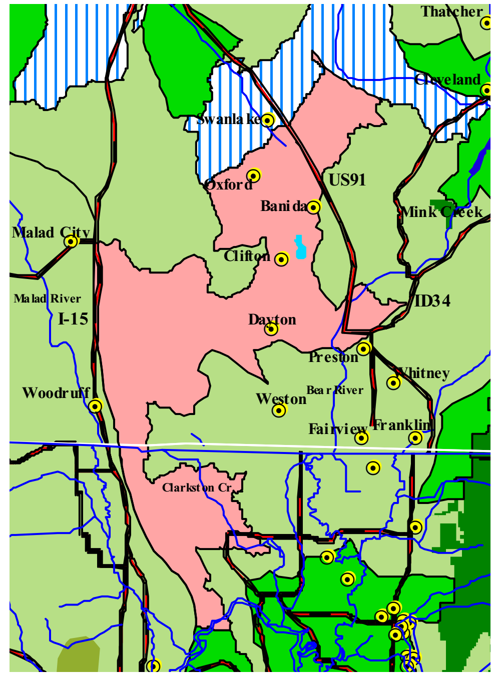
Site Description: The Bear River site straddles the Idaho-Utah border just north of Logan, Utah and takes in much of the northern Cache Valley. It includes Clarkson Creek in Utah and Henderson and Weston Creeks, Bear River, and Stockton Creek in Idaho. The area also includes the Malad Range in Idaho and the Bear River valley, plus many small communities like Clarkson, Weston, and Clifton. At one time extensive wetlands dominated the valley, but much has been converted to agriculture including a significant amount of row crops. Oxford Slough, a major wetland, remains in the north end of the site and supports large nesting colonies of Franklin's gull and white-faced ibis. Swan Lake, just north of Oxford Slough, used to harbor trumpeter swans and could be a potential swan restoration area. The higher elevations consist of gentle, rolling, open sagebrush-covered terrain with pockets of timber. Forested patches include extensive areas of aspen.

Targets List:

Animals:
Black tern
Black-crowned night-heron
Cattle egret
Common grackle
Eared grebe
Forsters tern
Franklins gull
Pinyon jay
Rock squirrel
Sharp-tailed grouse
Snowy egret
White-faced ibis
Whooping crane

Plants:
Red glasswort





Plant communities:
Akali bulrush
Akali cordgrass
Baltic rush
Bladder sedge
Common cattail
Curl-leaf mountain mahogany/bluebunch wheatgrass
Douglas-fir/mountain maple
Douglas-fir/mountain sweet-root
Foxtail barley
Greasewood/interior saltgrass
Hardstem bulrush
Interior saltgrass
Limber pine/curl-leaf mountain mahogany
Low sagebrush/bluebunch wheatgrass
Mountain big sagebrush/California brome
Nebraska sedge
Reed canarygrass
Thermal springs aquatic community
Threesquare bulrush

GAP vegetation:
Alpine Fir
Alpine Fir/Lodgepole
Doug Fir
Doug Fir or White Fir
Juniper Utah
Pinyon
Pinyon-Juniper
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Bitterbrush
Greasewood
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Salt Desert Scrub
Dry Meadow
Grassland
Lowland Riparian
Mt. Riparian
Wetland

Ownership: 67.7% private, 32.3% public

Possible Threats and Management Issues

- Conversion to Agriculture or Silviculture (along flatter private lands)
- Water Quality Degradation
- Drainage of Wetlands

Agricultural impacts in Gem Valley at Soda Point, Bear River Range. (C)George Wuerthner

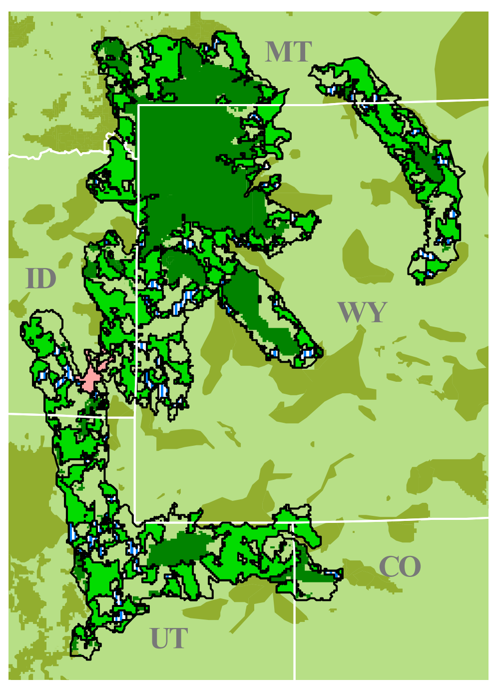
Site Name: Bear River Range
Size: 182,908 acres
Quadrant: 2
Irreplaceability Score: 57.2
Vulnerability Score: 23.9
Combined Score: 81.1

Site Description: This site in southeast Idaho straddles the northern end of the Bear River Range, which in turn is a northern extension of the Wasatch Range. Most of the higher elevation land is managed by the Cache National Forest. The range includes peaks to nearly 9,000 feet with forests of aspen, bigtooth maple, subalpine fir, lodgepole pine, and Engelmann spruce common on the slopes. Several small roadless areas in the range are proposed for wilderness, including the 35,000-acre Cache Crest area. The Bear River drains northward from Bear Lake and loops around Soda Point and into Gem Valley. Streams included in the site are Mink Creek, Williams Creek, Emigration Creek, North Creek, Coop Creek, Skinner Creek, and Eightmile Creek, among others. Bonneville cutthroat trout are native to this drainage, but most streams no longer hold viable populations. The flanks of this range are important mule deer winter range, and there are growing elk herds, with over 1000 in the range. The entire Bear River Range is important habitat for a number of rare mollusks. Most of the flat valley bottoms have been converted to agriculture.

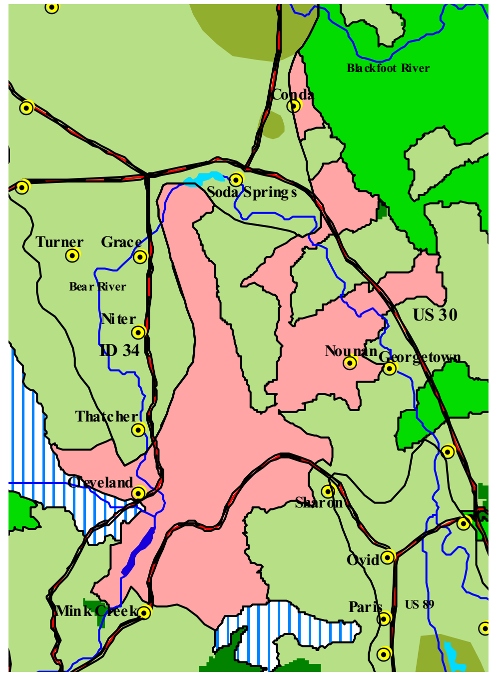
Targets List:

Animals:
Northern goshawk
Rock squirrel

Plant Communities:
Bigtooth maple/mountain sweet-root
Booth willow/water sedge
Box-elder/mountain sweet-root
Common cattail
Creeping spikerush
Curl-leaf mountain mahogany/bluebunch wheatgrass
Douglas-fir/curl-leaf mountain mahogany
Douglas-fir/mountain maple
Douglas-fir/mountain snowberry
Douglas-fir/mountain sweet-root
Douglas-fir/pinegrass pachistima phase
Douglas-fir/pinegrass pinegrass phase
Great Basin wildrye
Hardstem bulrush



Mountain big sagebrush-mountain
Snowberry/bluebunch wheatgrass
Mountain big sagebrush/bluebunch wheatgrass
Mountain big sagebrush/california brome
Populus tremuloides/*Thalictrum fendleri*
Quaking aspen-Douglas-fir/Saskatoon Serviceberry
Red-osier dogwood/sweetscented bedstraw
Short-beaked sedge
Subalpine fir/mountain maple
Subalpine fir/mountain sweet-root
Subalpine fir/pinegrass pinegrass phase
Thermal springs aquatic community
Threesquare bulrush
Travertine barrens
Water birch cover type
Water birch/red-osier dogwood



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Lodgepole
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Bitterbrush
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

Ownership: 37.4% private, 61.6% public

Possible Threats and Management Issues

- Conversion to Agriculture or Silviclture along Valley Bottoms (fragmentation)
- Improper Grazing Practices at the flanks and heights of the mountains
- Improper Irrigation Practices (high use, affect fisheries)
- Management for/of Elk (liberal harvest quota due to human land conflict)
- Residential Development

Shell Canyon. (C) George Wuerthner

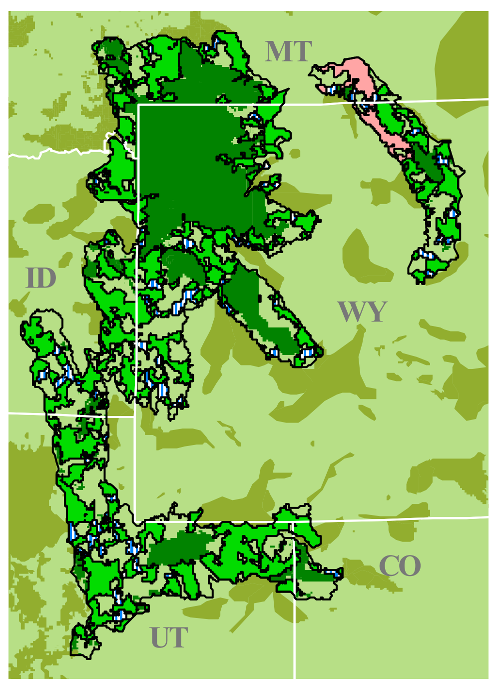
Site Name: Bighorn Canyon
Size: 560,287 acres
Quadrant: 2
Irreplaceability Score: 61.4
Vulnerability Score: 16.4
Combined Score: 77.8

Site Description: The Bighorn Canyon site takes in the northwest corner of the Bighorn Mountains on the Montana-Wyoming border. It nearly surrounds the Bighorn Canyon NRA and is adjacent to the Crow Indian Reservation. The southeast corner of the site borders the northern tip of the Cloud Peak Wilderness. It is adjacent to a TNC Wyoming Basins portfolio site. Starting from the south, the watersheds included are upper Shell Creek , upper Porcupine Creek, Black Canyon Creek, Beauvais Creek, and Pryor Creek. The area is named for the abundance of wild bighorn sheep that once roamed the range. The Bighorns rise steeply from the Bighorn Basin to relatively rolling meadow-dotted terrain on the top of the mountains. Deep limestone canyons dotted with juniper give the slopes a southwest canyon appearance. Moose, elk, and deer are common. Isolation may have created genetically distinct populations of snowshoe hare, marten, and other species in the Bighorns.

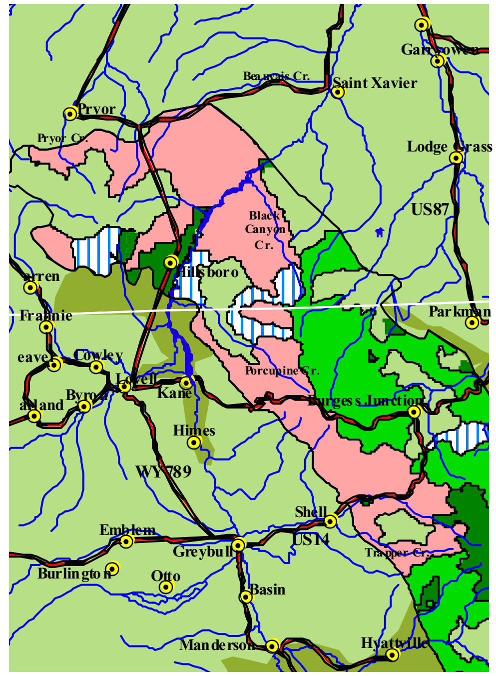
Targets List:

Animals:
Peregrine falcon
Three-toed woodpecker
Water vole
Wood frog
Yellowstone cutthroat trout

Plants:
Aromatic pussytoes
Bighorn fleabane
Cary beardtongue
Coil-beaked lousewort
Cut-leaved groundsel
Hapemans sullivantia
Joe-pye weed
Lettermans needlegrass
Northern arnica
Pink agoseris
Pregnant sedge
Shoshonea



Slender wedgegrass
Soft aster
Sweetwater milkvetch
Wyoming sullivantia



Plant Communites:
Limber pine/curl-leaf mountain mahogany
Narrow-leaf cottonwood/choke cherry
Populus angustifolia / Rosa woodsii Forest
Redosier dogwood/sweetscented bedstraw

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Juniper Western
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Spruce
Whitebark/Limber Pine
Aspen/Conifer
Burn Shrub
Greasewood
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Salt Desert Scrub
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 17.1% private, 82.9% public

<u>Possible Threats and Management Issues</u>

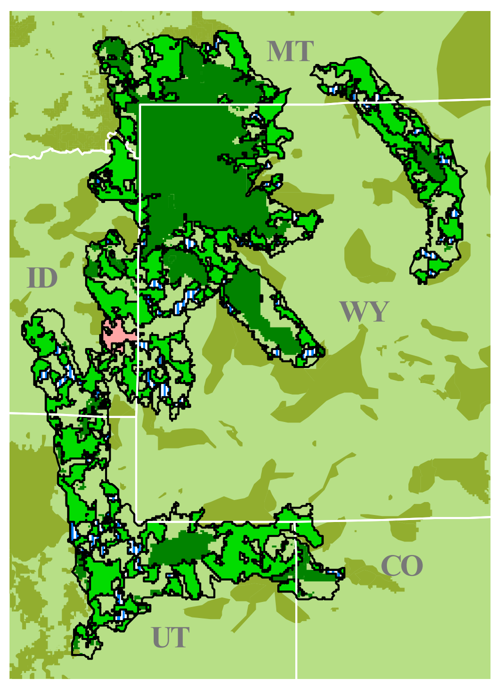
- Improper Grazing Practices (Domestic Sheep preclude establishment of Big Horn in area)
- Degradation of Riparian Areas (due to high stocking rate)
- Developed Logging Road Network (use exceeds road densities for habitat effectiveness for elk)

Blackfoot River near Henry. (C)George Wuerthner

Site Name: Blackfoot-Salt
Size: 207,700 acres
Quadrant: 2
Irreplaceability Score: 87.8
Vulnerability Score: 38.8
Combined Score: 126.6

Site Description: The Blackfoot-Salt site includes, from the south northward, the following drainages: Slug Creek, Stump Creek, Diamond Creek, Lanes Creek, Blackfoot River, Trail Creek, and Little Blackfoot River. The Blackfoot Valley is bordered on the east by a number of small ranges including the Wooley Range, Grays Range, and Aspen Range. Many of these ranges are part of the Southeast Idaho phosphate belt. As recently as 600,000 years ago basalt lava flows poured across the valley. There are still numerous reminders of this era, including old cones and flows. The Blackfoot River was once a major producer of large cutthroat trout. One creel survey in the 1950s showed that 20% of the fish removed from the river exceeded 20 inches, and cutthroat up to 15 pounds were recorded. Heavy fishing pressure, combined with degraded water quality, led to the decline of this fisheries. Nevertheless, such statistics demonstrate the potential for restoration of fisheries in the upper Blackfoot drainage. The area supports substantial aspen parklands and willow bottoms that are important for a variety of wildlife including songbirds and herbivores like moose, elk, and deer.

Targets List:

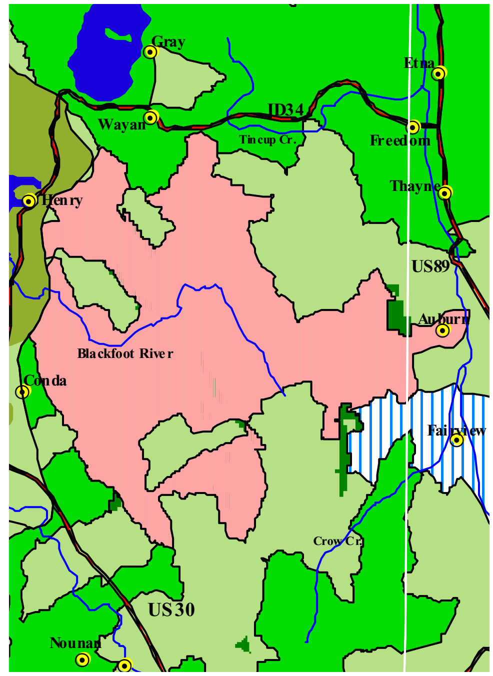


Animals:
Boreal owl
Great gray owl
Long-billed curlew
Northern goshawk
Northern leopard frog
Whooping crane

Plants:
Idaho sedge
Red glasswort

Plant communities:
Bladder sedge
Booth willow/bladder sedge
Booth willow/bluejoint reedgrass
Booth willow/Kentucky bluegrass
Booth willow/mesic graminoid

Creeping spikerush
Douglas-fir/pinegrass
Engelmanns spruce/bluejoint reedgrass
Geyer willow/water sedge
Mountain alder/red-osier dogwood
Mountain big sagebrush/idaho fescue
Nebraska sedge
Needle spike-rush
Red-osier dogwood
Short-beaked sedge
Silver sage/Kentucky bluegrass
Silver sagebrush/tufted hairgrass
Subalpine fir/blue huckleberry grouse Whortleberry phase
Subalpine fir/buffalo-berry
Subalpine fir/common snowberry
Subalpine fir/grouse whortleberry pinegrass phase
Subalpine fir/mountain maple pachistima phase
Subalpine fir/mountain ninebark
Subalpine fir/mountain sweet-root pachistima phase
Subalpine fir/pinegrass pinegrass phase
Tufted hairgrass
Water sedge
Wolfs willow/water sedge
Woolly sedge



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Aspen
Aspen/Conifer
Maple
Montane Shrub
Mountain Sage
Sagebrush Steppe
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow

Barren
Lowland Riparian
Mt. Riparian

Ownership: 47.7% private, 52.3% public

Possible Threats and Management Issues

- Mining Practices (strip mining of phosphate; 5000-6000 acres)
- Water Quality Degradation (heavy mental contaminants)
- Conversion to Agriculture or Silviculture
- Irrigation Practices (dewatering and siltation)
- High Potential for Future Mining (10,000+ government acres to be released)

Main Boulder River Valley. (C) George Wuerthner

Site Name: Boulder-Stillwater
Size: 240,212 acres
Quadrant: 4
Irreplaceability Score: 15.8
Vulnerability Score: 38.8
Combined Score: 54.6

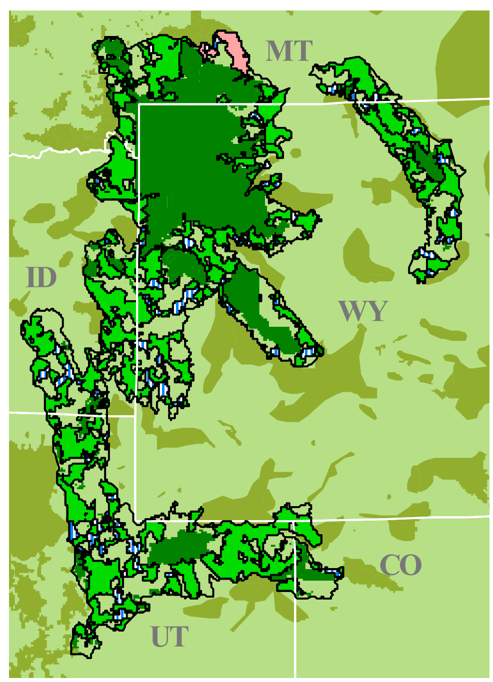
Site Description: The Boulder-Stillwater site includes the upper portions of the Boulder River and Stillwater River. It also includes the West and East Roadbud drainages, upper and lower Deer Creek, Main Boulder and East Boulder Rivers, and Fishtail Creek. The site lies immediately adjacent to the Absaroka-Beartooth Wilderness. It is immediately adjacent to a TNC Northern Plains Ecoregion site. The Beartooth Mountains rise dramatically and abruptly to heights of more than 12,000 feet. Foothills valleys are transitional between the plains and uplands, with patches of aspen, Engelmann spruce, and Douglas-fir common. Ponderosa pine is found at the lowest elevations from the Deer Creeks eastward. The Deer Creeks have some large deer herds. Elk are found along the flanks of the Beartooth Mountains, with several small bighorn sheep herds in the Rosebud, Boulder, and Stillwater drainages. Individual grizzly bears and wolves have been recorded in the area recently, although no breeding populations are yet documented. Harlequin ducks are reported for the Boulder River.

Targets List:

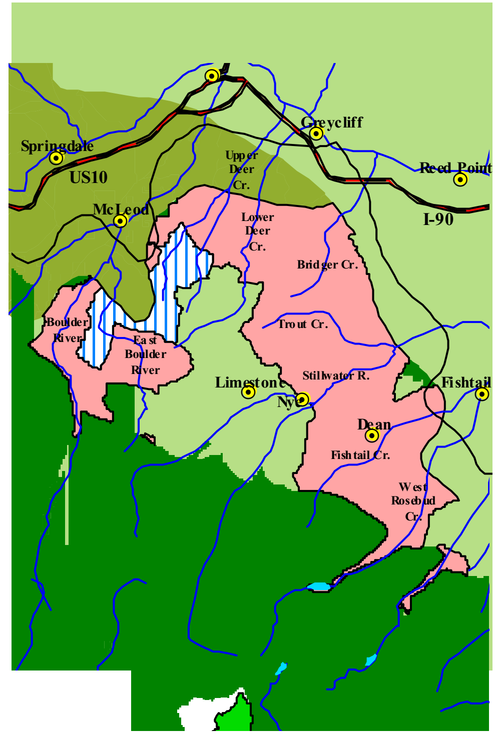
Animals:
Peregrine falcon

Plants:
Beaked spikerush
Hikers gentian
Long sheath waterweed
Small-winged sedge

GAP vegetation:
Doug Fir
Fir/Lodgepole Pine
Juniper Utah
Juniper Western
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Whitebark/Limber Pine
Aspen/Conifer
Burn Shrub



Montane Shrub
Mountain Sage
Sagebrush Steppe
Salt Desert Scrub
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland



<u>Ownership</u>: 48.1% private, 51.9% public

<u>Possible Threats and Management Issues</u>

- Improper Livestock Production Practices
- Conversion to Agriculture or Silviculture
- Improper Irrigation Practices (dewatering)
- Residential Development (Stillwater area)
- Mining Practices
- Residential Development (Big Timber & Absarokee areas)

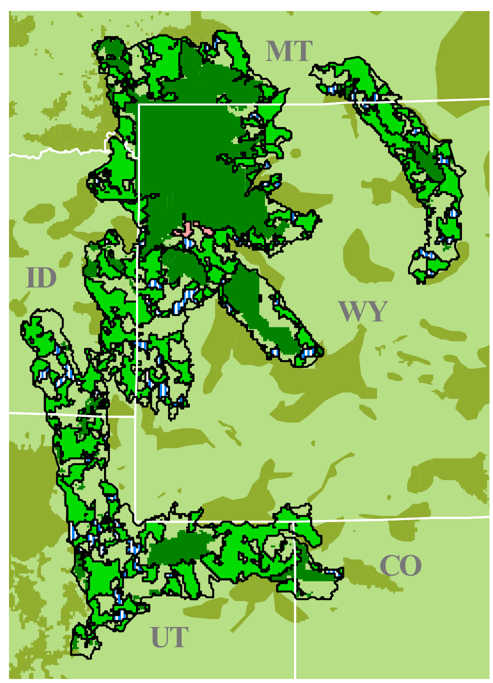
Buffalo Fork River and Tetons. (C) George Wuerthner

Site Name: Buffalo Fork
Size: 76,479 acres
Quadrant: 2
Irreplaceability Score: 64.0
Vulnerability Score: 9.0
Combined Score: 73.0

Site Description: The Buffalo Fork site includes the Buffalo Fork River from Moran Junction to Togwotee Pass. The site lies just south of the Teton Wilderness, with the Mount Leidy Highlands to the south and Grand Teton National Park to the west. The site includes Spread Creek, Pacific Creek, and Blackrock Creek. There are extensive meadows interspersed with timber including large stands of aspen, plus lodgepole pine, Douglas-fir, Engelmann spruce, and subalpine fir. The area has extremely high wildlife values. There are large riparian willow thickets along the Buffalo Fork and tributary streams that host hundreds of moose. In addition, huge herds of resident and migrant elk pass through this area annually, plus some wild bison that roam in and around GTNP. Pacific Creek is home to Yellowstone cutthroat trout. Both grizzly and wolf populations are increasing in the area. The Mount Leidy Highlands contain a large roadless area proposed for wilderness protection. As a crucial corridor for wildlife moving north and south through this part of Wyoming, protecting this linkage is very important.

Targets List:

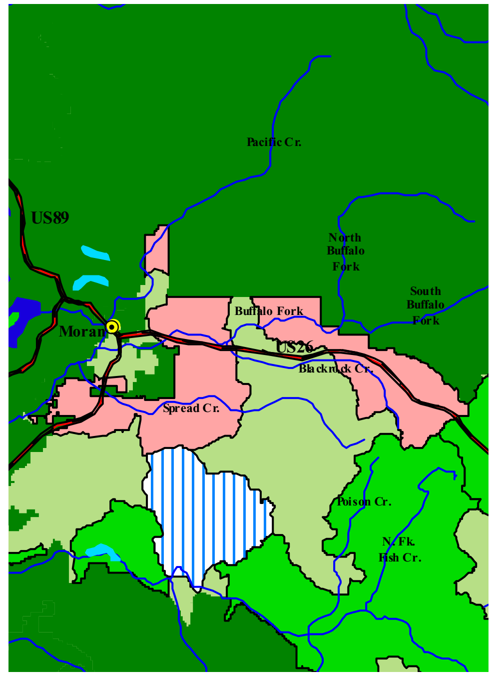
Animals:
Bald eagle
Columbia spotted frog
Flammulated owl
Three-toed woodpecker
Western boreal toad
Whooping crane



Plants:
Aromatic pussytoes
Teton golden-aster
Teton wire-lettuce
Wyoming tansymustard

GAP vegetation:
Alpine Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Lodgepole Pine

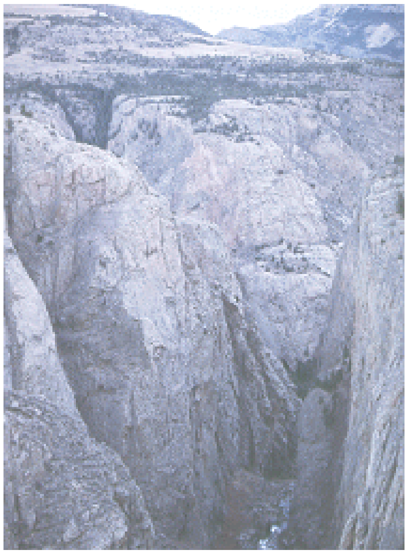
Lodgepole
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Alpine Herbaceous
Dry Meadow
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland



<u>Ownership</u>: 10.1% private, 89.9% public

<u>Possible Threats and Management Issues</u>

- Degradation of Riparian Areas (due to Hay Production)
- Predator Conflict (domestic livestock vs. grizzlies & wolves)
- Improper Grazing Practices (forage competition between native ungulates and livestock)
- Residential Development (Buffalo Fork)
- High Use Roadways (State Highway 26 Expansion)
- Past Logging Practices
- Past Network of Backcountry Roads (Spread Creek drainage)



Canyon of Clarks Fork of the Yellowstone. (C) George Wuerthner

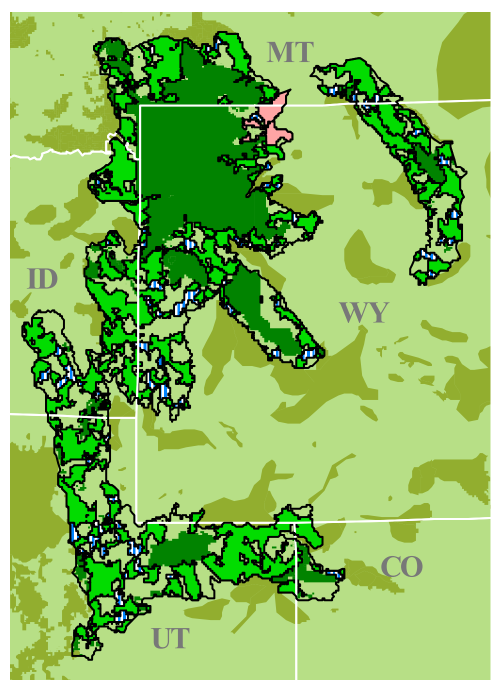
Site Name: Clark Fork
Size: 298,774 acres
Quadrant: 2
Irreplaceability Score: 68.6
Vulnerability Score: 38.8
Combined Score: 107.4

Site Description: The Clark Fork site lies on the eastern slope of the Absaroka Mountains and along the southern edge of the Beartooth Mountains. The Wild and Scenic Clark Fork River runs through the site. It also includes the Line Creek Plateau on the northwest corner and the Sunlight Basin on the western edge. On the south are the headwaters of Pat O''Hara Creek, Paint Creek, Alkali Creek, Sunlight Creek, Crandall Creek, Russell Creek, Lake Creek, Bennett Creek, and Line Creek on the Montana-Wyoming border. North of the border lies Grove Creek off the Line Creek plateau. Much of the area is protected as part of the North Absaroka and Absaroka-Beartooth Wilderness. There are, however, some significant unprotected lands, particularly in the Sawtooth Lake area and Line Creek Plateau. Extensive areas of alpine tundra dominate some of the higher plateaus in the Beartooth Mountains. The area has limited private land, mostly lying along the rivers and tributaries. The Absaroka Mountain portion of the area supports some large elk herds, some large bighorn sheep herds, and mountain goats in the Beartooth Mountains (exotic). Numerous rare plants are found on the Beartooth Plateau and adjacent limestone areas along the edges of the mountains. Crandall Creek has a known genetically-pure population of Yellowstone cutthroat trout.

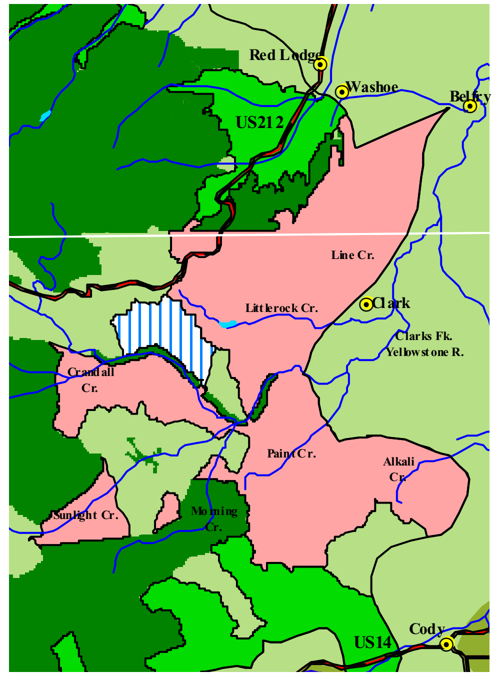
Targets List:

Animals:
Columbia spotted frog
Northern goshawk
Trumpeter swan
Western boreal toad

Plants:
Absaroka biscuitroot
Absaroka goldenweed
Aromatic pussytoes
Barratt willow
Beartooth large-flowered goldenweed
Cocks-comb paintbrush
False uncinia sedge
Greenland primrose
Halls fescue



Howard forget-me-not
Hutchinsia
Koenigia
Livid sedge
Marsh muhly
Myrtleleaf willow
Nelsons sedge
Pink agoseris
Red manzanita
Rolland bulrush
Round-leaved orchid
Shoshonea
Siberian kobresia
Simple kobresia
Snow paintbrush
Taprooted fleabane
Teton golden-aster
White arctic whitlow-grass



Plant communities:
Engelmann spruce/revolute hypnum moss
Pinus flexilis / Juniperus communis Woodland
Ross avens-trifolium spp.?

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Juniper Western
Lodgepole
Pinyon-Juniper
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Burn Shrub
Greasewood
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Grassland
Wet Meadow

Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 30.7% private, 69.3% public

<u>Possible Threats and Management Issues</u>

- Improper Grazing Practices (particularly trampling of riparian areas)
- Conversion to Agriculture or Silviculture (Clark's Fork area)
- Predator Conflict
- Disease Transmission to Native Species (particularly Big Horn Sheep)
- Degradation of Aquatic Habitats (extirpation of Water Shrews)
- Residential Development
- Improper Salvage Logging
- Road Upgrades & Maintenance (affecting wintering wildlife)


Arid rangelands near Cottonwood Creek. (C) George Wuerthner

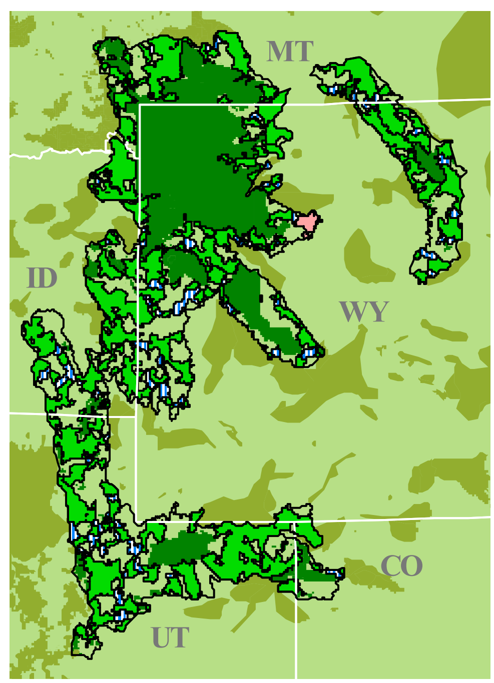
Site Name: Cottonwood Creek
Size: 98,597 acres
Quadrant: 2
Irreplaceability Score: 54.6
Vulnerability Score: 38.8
Combined Score: 93.4

Site Description: This site lies on the eastern slopes of the Absaroka Mountains northeast of Thermopolis. It includes its namesake, Cottonwood Creek. Other drainages in the site include Twentyone Creek and Cottonwood Creek in the south, with Grass Creek, Little Grass, and Enos Creek in the north. The land is nearly all under BLM management. Generally low elevation and extremely arid, the site consists of rolling sagebrush-grass terrain with some juniper and pockets of aspen. Cottonwood is found along the major streams. The high areas closer to the Absaroka Range are utilized by elk, while mule deer are abundant at lower elevations. Recent grizzly and wolf sightings have occurred in the area. If populations of these predators reach self-sustaining levels, this area could help to sustain viable populations of these animals in the surrounding region.

Targets List:

Plants:
Rocky Mountain twinpod

GAP vegetation:
Alpine Fir
Doug Fir
Fir/Lodgepole Pine
Juniper Utah
Lodgepole
Pinyon-Juniper
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Burn Shrub
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Grassland
Wet Meadow

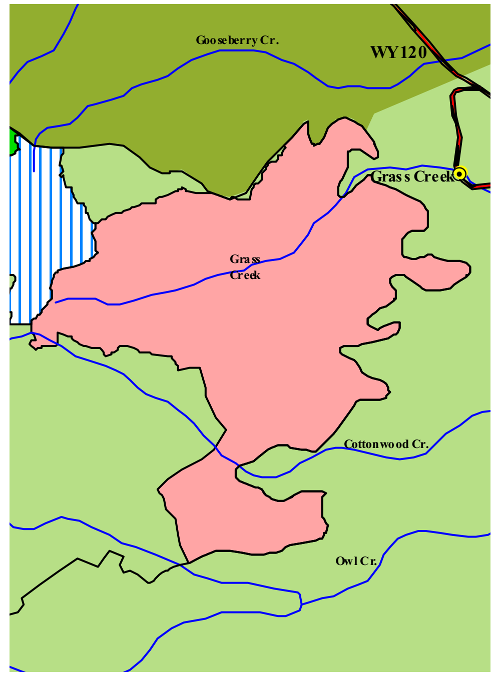


Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 42.4% private, 57.6% public

<u>Possible Threats and Management Issues</u>

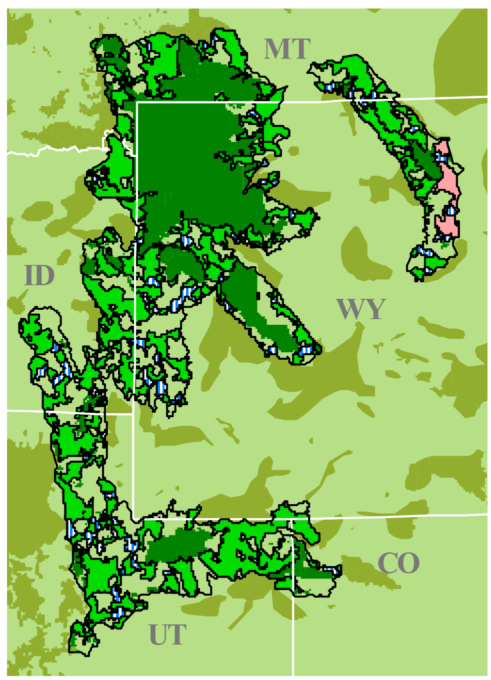
- Livestock Production Practices
- Irrigation Practices (dewatering)
- Conversion to Agriculture or Silviculture
- Predator Conflict
- Residential Development (near Thermopolis)
- Oil and Gas Development



Bighorn Mountains near Clear Creek.
(C) George Wuerthner

Site Name: Crazy Woman
Size: 328,075 acres
Quadrant: 2
Irreplaceability Score: 70.6
Vulnerability Score: 46.3
Combined Score: 116.9

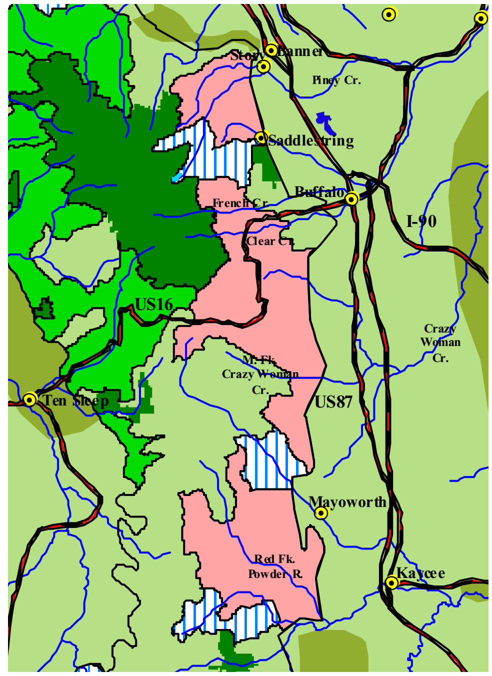
Site Description: The Crazy Woman site is located on the eastern slope of the Bighorn Mountains. Starting in the south, the site is drained by the Red Fork of the Powder River, upper portion of the Middle Fork Power, Poison Creek, Billy Creek, Muddy Creek, North Fork Crazy Woman Creek, and the upper watershed of Clear Creek. The Bighorn Mountains are an island range, isolated from other mountain areas. They rise steeply from the plains, and the eastern slope catches a significant amount of summer precipitation and is considerably wetter than the western side of the mountains. The lowest elevations are dominated by grasslands that grade into ponderosa pine forests. Higher elevations consist of numerous flowery subalpine parklands interrupted by stands of lodgepole pine, Engelmann spruce, and subalpine fir. There are also extensive areas of aspen. The floral composition is more closely aligned with the Colorado Front Range and southern Rockies than the Northern Rockies. As a boreal isolate, there is speculation that marten, water voles, and snowshoe hare, among other species, are genetically distinct. Elk herds in the southern Bighorns are expanding, and several thousand exist on Forest Service and BLM lands. A wolverine was recently photographed at the base of the Bighorns near Buffalo. Moose are expanding in this range, while bighorn sheep, for whom the range is named, are nearly extirpated due to conflicts with livestock. Antelope will occasionally range up to 9,000 feet in this area.



Targets List:

Animals:
Dwarf shrew
Northern goshawk
Northern leopard frog
Three-toed woodpecker
Townsends big-eared bat

Plants:
Coil-beaked lousewort
Crenulate moonwort
Hapemans sullivantia
Mountain ladys-slipper
Nagoonberry
Northern arnica



Pink agoseris
Soft aster
Williams spring-parsley

Plant communities:
Quaking aspen/silver-stem lupine
Tufted hairgrass-small wing sedge

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Spruce
Aspen/Conifer
Greasewood
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 34.9% private, 65.1% public

<u>Possible Threats and Management Issues</u>

- Improper Grazing Practices (forage competition, riparian areas)
- Irrigation Practices (dewatering of streams)
- Improper Logging Practices (forest fragmentation & road development)
- Residential Development (around base of the mountains)

Southeast slope of Unita Mts. (C) George Wuerthner

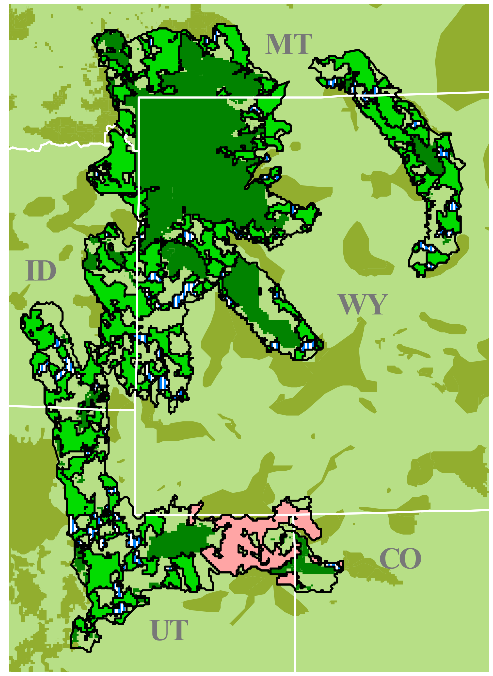
Site Name: East Uintas
Size: 1,225,041 acres
Quadrant: 3
Irreplaceability Score: 38.8
Vulnerability Score: 83.6
Combined Score: 122.4

Site Description: The East Uintas site—the largest megasite in this portfolio—takes in the entire eastern portion of the Uinta Range. It is bordered on the west by the High Uinta Wilderness and on the south by Dinosaur National Monument. There are a host of TNC portfolio sites that border this site on the south, east, and north. Drainages in this site include the Green and Yampa Rivers. The site includes Cold Mountain on the northwest corner. Elevations rise from 5200 feet near Vernal to over 12,000 feet on some of the higher mountains. The higher elevations were heavily glaciated, and there are numerous lakes, cirques, and other evidence of past glaciation. The Uinta Range is the wettest area in Utah and the source for numerous rivers in the state. Drainages within the site include South Fork Cub Creek, Brush Creek, Ashley Creek, Dry Fork, Deep Creek, East Channel Uinta River, Whiterocks River, and Farm Creek. On the north slope are Dahlgreen Creek, Birch Ceek, Sheep Creek, Carter Creek, Red Creek, all in Utah, while in Wyoming are Red Creek and Little Red Creek. There are a number of large roadless areas in this region including Cold Mountain in Colorado, more than 200,000 acres in the Dinosaur National Monument, and more than 150,000 acres in the Uintas.

The area is a transition zone between the Southern Rockies, Middle Rockies, and the Colorado Plateau. As such it is extremely rich in species diversity. The northern or southern range limits of many species occur in this general areas. For instance, the cliff chipmunk, pinyon mouse, and canyon mouse all reach their northern limits here. Lower elevations include pinyon juniper woodlands that grade up through ponderosa pine forests and eventually into subalpine meadowlands with extensive aspen groves. The highest elevations are dominated by alpine tundra. Blue spruce and narrowleaf cottonwood are found along riparian areas. Elk are abundant, with herds growing in the area, while mule deer are the dominant ungulate. Both wolverine and lynx have been reported for the Uintas and may still be here. Other rare species include Wyoming ground squirrel and northern flying squirrel. There are a number of rare fish species in the Green River and its tributaries, including Colorado cutthroat trout, bonytail chub, Colorado River pike minnow, and others. Rare plant communities and species are numerous.

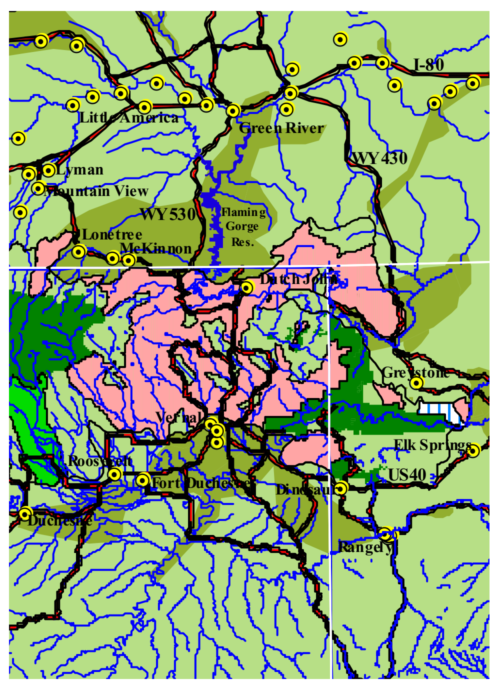
We expected that this important site would fall into Quadrant 1. However, because this is a very large site with many planning units, and irreplaceability values for each criterion (except #4, focal species viability) represent area-weighted means of sum runs values of all planning units in the megasite, it appears that planning units with lower values dragged the averages down. These problems can be resolved through the increased resolution of site-level planning. Also, we note that although this megasite scored high for species targets and some other criteria, it scored relatively low for others, such as focal species habitat.

Targets List:



Animals:
Bear Lake sculpin
Colorado pikeminnow
Colorado River cutthroat trout
Eureka mountainsnail
Humpback chub
Northern goshawk
Osprey
Sage sparrow
Smooth green snake
Three-toed woodpecker
Townsends big-eared bat
Wolverine

Plants:
Blue Mountain beardtongue
Bristly-stalk sedge
Caespitose cats-eye
Clustered ladys-slipper
Compound kobresia
Dinosaur milkvetch
Echo spring-parsley
Everts waferparsnip
Gibbens beardtongue
Goodrich penstemon
Grahams columbine
Grass milkvetch
Hamilton milkvetch
Huber peppergrass
Juniper whitlow-grass
Ligulate feverfew
Marsh cinquifoil
Mountain clover
Murdocks thistle
Naked-stemmed wallflower
Narrow-leaf evening primrose
Narrow-leaved skeletonplant
One-flower wintergreen
Opal phlox
Ownbey thistle
Palmers cleomella
Park rock cress
Payson beardtongue



Penlands beardtongue
Rock hymenoxys
Rockcress draba
Silvery primrose
Stemless beardtongue
Tufted cryptanth
Uintah beardtongue
Ute ladies tresses
Vernal narrow-leaf penstemon
WhiteRriver penstemon
Woodside buckwheat
Yampa beardtongue

Plant communities:
Cold desert shrublands
Mesic western slope pinyon-juniper woodlands
Mixed mountain shrublands
Western slope grasslands
Western slope sagebrush shrublands
Xeric western slope pinyon-juniper woodlands

GAP vegetation:
Alpine Fir/Spruce
Doug Fir
Doug Fir or White Fir
Juniper Utah
Lodgepole
Lodgepole/Aspen
Pinyon
Pinyon-Juniper
Ponderosa Pine
Aspen
Aspen/Conifer
Mountain Mahogany
Oak
Bitterbrush
Greasewood
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Salt Desert Scrub
Alpine Herbaceous
Desert Grassland
Dry Meadow

Grassland
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian

Ownership: 19.0% private, 81.0% public

Possible Threats and Management Issues

- Dam Operations (Green River; causes change in water flow pattern)
- Invasive Species (Tamarisk along riparian areas)
- Irrigation Practices (dewatering for livestock)
- Disease Transmission to Native Wildlife (particularly Big Horn Sheep)
- Oil & Gas Exploration (at lower elevations)
- Logging of Pocket Timber (at higher elevations)

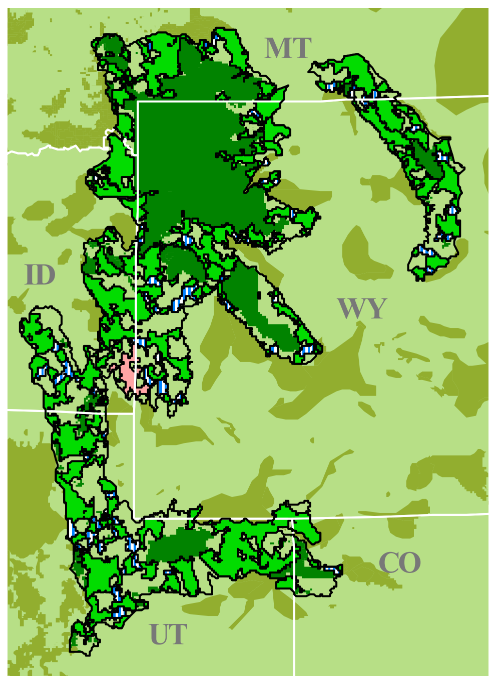
Gannett Hills along Idaho-Wyoming border. (C) George Wuerthner

Site Name: Gannett Hills
Size: 219,983 acres
Quadrant: 2
Irreplaceability Score: 55.1
Vulnerability Score: 31.3
Combined Score: 86.4

Site Description: The rolling, aspen-covered Gannett Hills are located in the center of this site, which includes the headwaters of the Salt River, Thomas Fork, and Montpelier Creek. It is bordered on the south by a site in TNC's Wyoming Basins portfolio. Watersheds include Thomas Fork, Montpelier Canyon, Preuss Creek, Crow Creek, and White Dugway Creek, and in Wyoming, Muddy Creek and Salt Creek are both tributaries of the Thomas Fork. The area has some of the highest big game values in Idaho, including large herds of elk and moose. Tributaries of the Thomas Fork contain Bonneville cutthroat trout.

Targets List:

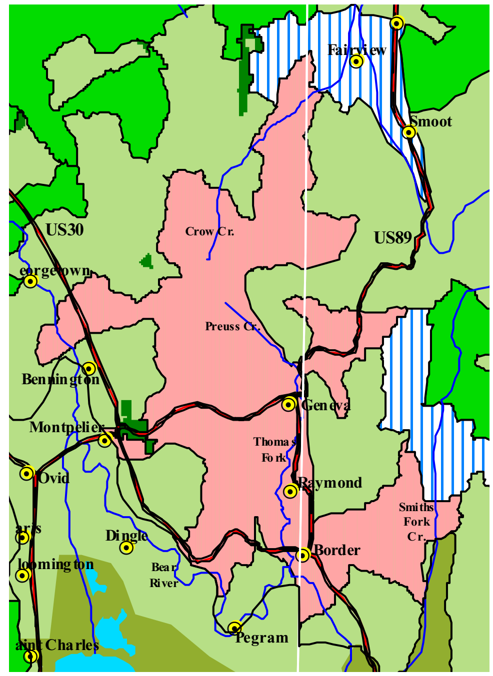
Animals:
Bald eagle
Black tern
Bluehead sucker
Bonneville cutthroat trout
Fine-spotted Snake River cutthroat
Forsters tern
Leatherside chub
Merriams shrew
Northern goshawk
Townsends big-eared bat
Western small-footed myotis
White-faced ibis
Wolverine



Plants:
Red glasswort
Starveling milkvetch
Uinta Basin cryptantha

Plant communities:
Baltic rush
Bladder sedge
Bog birch/short-beaked sedge
Booth willow/bladder sedge

Booth willow/common horsetail
Booth willow/mesic forb
Booth willow/mesic graminoid
Clustered field sedge
Common cattail
Coyote willow/mesic graminoid
Creeping spikerush
Engelmann spruce/common horsetail
Foxtail barley
Geyer willow/mesic graminoid
Hardstem bulrush
Interior saltgrass
Mat muhly
Red-osier dogwood
Short-beaked sedge
Softstem bulrush
Tufted hairgrass
Water sedge
Wolfs willow/water sedge
Woolly sedge



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Mountain Mahogany
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian

Mt. Riparian
Wetland

Ownership: 40.1% private, 59.9% public

Possible Threats and Management Issues

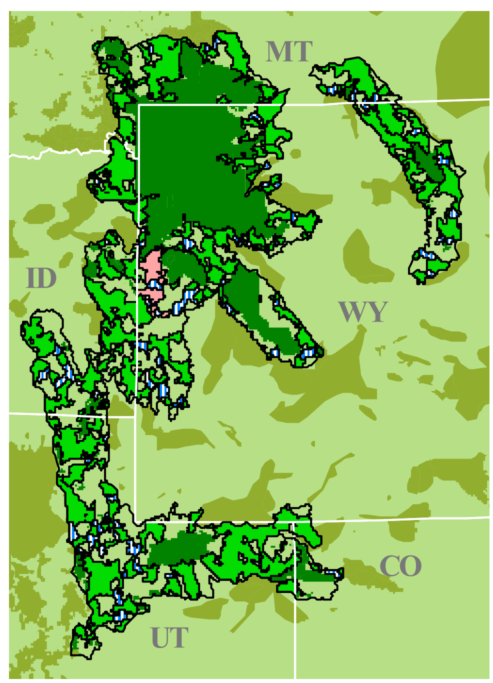
- Livestock Production Practices
- Conversion to Agriculture or Silviculture
- Irrigation Practices (dewatering)
- High Use Roadways (Highway 89 – affect migratory wildlife)

Headwaters of Little Grey's River. (C) George Wuerthner

Site Name: Grey's River
Size: 271,987 acres
Quadrant: 3
Irreplaceability Score: 39.3
Vulnerability Score: 83.6
Combined Score: 122.9

Site Description: The Grey's River site borders the Gros Ventre Wilderness and Grand Teton National Park and takes in some large roadless areas to the south, including portions of the Grayback Ridge area and Palisades. The mountains here are extremely rugged and include the north end of the Wyoming Range, sometimes referred to as the Hoback Range, as well as portions of the southern slope of the Gros Ventre Mountains and the very steep Palisades portion of the Snake River Range. This site includes Jackson and other small communities. It is drained by the South Fork of the Snake River. Starting on the southeast is Deadman Creek, White Creek, Grey's River, Little Grey's River, Red Creek in Palisades, Fall Creek, Mosquito Creek, Spring Creek, Fish Creek, and lower Gros Ventre River. The area has high wildlife values including large herds of elk, moose, and mule deer. A few small, relict herds of bighorn sheep persist in the Little's Grey's River drainage. Fine-spotted cutthroat trout are found in some of the Snake tributaries. Exotic mountain goats are found in the Palisades and are spreading into other mountain areas. Grizzly bears are expanding into the northern portion of this site. Lynx have been found here recently.

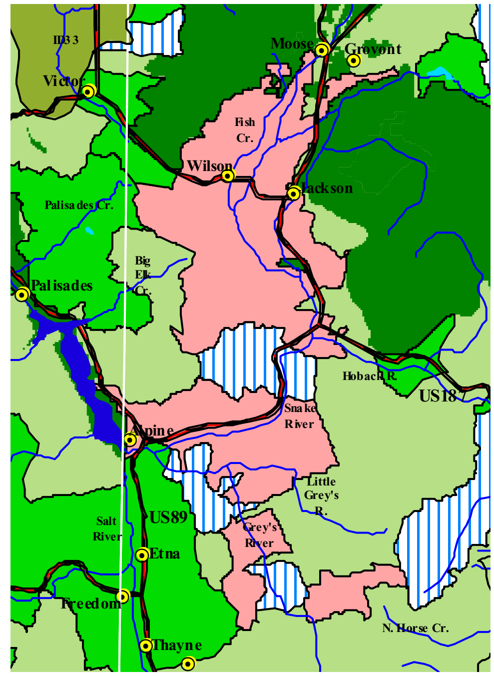
Targets List:



Animals:
Bald eagle
Boreal owl
Flammulated owl
Great gray owl
Harlequin duck
Peregrine falcon
Whooping crane

Plants:
Boreal draba
Fernald alkali-grass
Giant helleborine
Keeled bladderpod
Paysons bladderpod
Paysons milkvetch
Rockcress draba
Shultzs milk-vetch

Single-head pussytoes
Teton golden-aster



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Burn Shrub
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

Ownership: 25.1% private, 74.9% public

Possible Threats and Management Issues

- Oil & Gas Exploration and Drilling
- Residential Development
- Predator Conflict
- Past Logging Practices (affect lower elevation drainages)
- Past Roads for Logging and Oil & Gas Exploration


Headwaters of Greybull River, Absaroka Mts. from the air. (C) George Wuerthner

Site Name: Greybull
Size: 48,022
Quadrant: 4
Irreplaceability Score: 13.3
Vulnerability Score: 38.8
Combined Score: 52.1

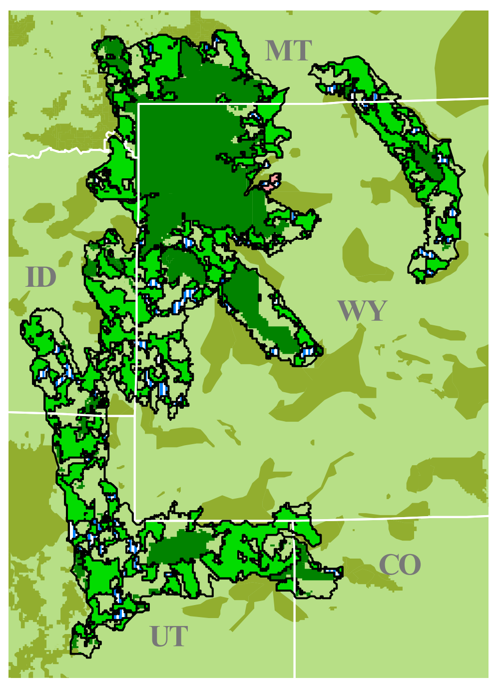
Site Description: The Greybull site lies on the eastern slope of the Absaroka Mountains, bordered on two sides by TNC portfolio sites in the adjacent Wyoming Basins ecoregion. Peaks in these mountains exceed 13,000 feet. The Waskakie Wilderness forms the western border of the site. One of the largest state holdings of land in Wyoming lies in this drainage. The site includes the upper watersheds of the following streams: Willow Creek, Pickett Creek, Meeteese Creek, Carter Creek, and Marquette Creek, with Belnap Creek and Crane Creek found on the north. Most of the lower elevations are dominated by sagebrush-grasslands, while uplands have numerous open meadows interspersed with forests of lodgepole pine, aspen, Engelmann spruce, and subalpine fir. Elk and mule deer are numerous here, along with some of the larger concentrations of bighorn sheep in the state. The site is increasingly used by grizzly bears and a number of recent wolf sightings are reported for the area. The last known wild black-footed ferret population was found on the Pitchfork Ranch in this site.

Targets List:

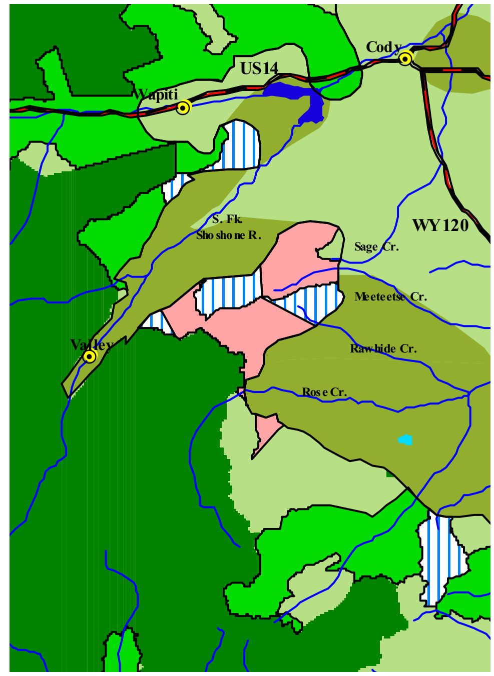
Animals:
Yellowstone cutthroat trout

Plants:
Absaroka beardtongue
Alpine poppy
Kings campion
Wyoming tansymustard

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Pinyon-Juniper
Spruce
Whitebark/Limber Pine
Burn_Shrub
Montane Shrub
Mountain Sage



Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian



<u>Ownership</u>: 14.8% private, 85.2% public

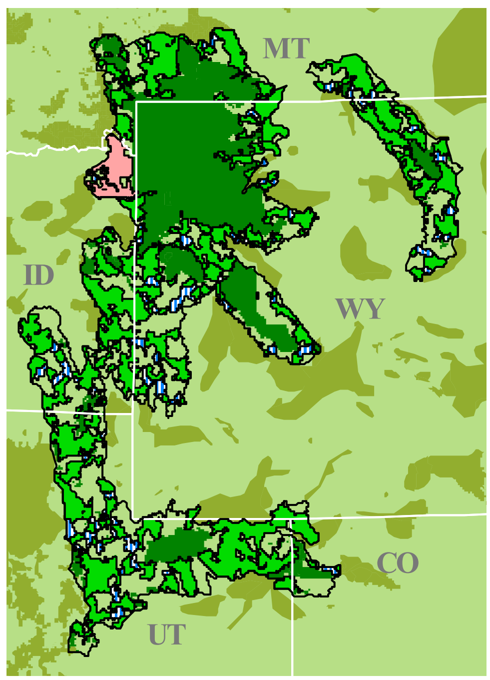
<u>Possible Threats and Management Issues</u>

- Livestock Production Practices
- Irrigation Practices (dewatering of streams)
- Oil & Gas Exploration
- Development on Land Sold by the State of WY

Henry's Lake from Sawtell Peak. (C) George Wuerthner

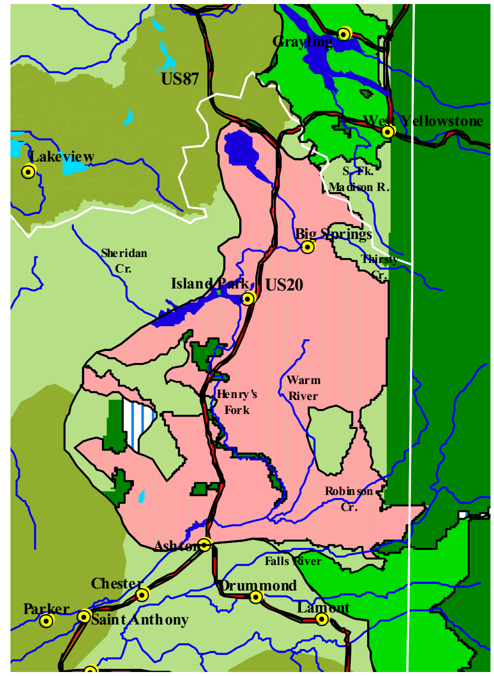
Site Name: Henry's Fork
Size: 450,148 acres
Quadrant: 1
Irreplaceability Score: 94.4
Vulnerability Score: 61.2
Combined Score: 155.6

Site Description: The Henry's Fork site lies west of Yellowstone National Park and immediately adjacent to it. It borders a TNC Columbia Basin site. Besides the upper Henry's Fork, drainages in the site include Warm River and Robertson Creek. Sand Creek forms the southwest border, and Yale Creek is in the northeast corner. This site includes Harriman State Park and the famous Mesa Falls scenic area. It borders on the Centennial Range and Lionhead area on the north. The Sand Creek Wildlife area lies on the southeast border. Harriman Ranch State Park, one of the largest state parks in Idaho, also occupies a portion of the site. Though significant Douglas-fir forests are found on the southern slope of the Centennial Range, most of the higher elevations are covered primarily by lodgepole pine with some subalpine fir and Engelmann spruce. Much of the Targhee National Forest in this area was heavily cut for several decades, leaving behind a huge road system and highly fragmented forest cover. North of Macks Inn there are extensive wet meadows. Indeed, the Idaho Fish and Game rates the Henry's Fork drainage as having some of the best wetlands left in Idaho. The Henry's Fork provides significant winter habitat for trumpeter swan, though populations are declining. This is one of the best places in Idaho for great gray owls, and boreal owls are known from several locations in the mountains adjacent to Henry's Lake. The area is also increasingly used by grizzlies, particularly in the south Island Park and Bitch Creek areas. One of the last fishers to be trapped in southeast Idaho was taken in this area. A migratory population of antelope summers in the Henry's Lake area and winters in the Madison Valley. Reintroduction of Yellowstone cutthroat trout is currently underway within Harriman State Park; however, in general the Henry's Fork is being managed for the non-native rainbow trout, which has led to the decline of native fish. This site has the highest irreplaceability score of any megasite in this portfolio.



Targets List:

Animals:
Bald eagle
Black tern



Boreal owl
Bufflehead
Columbian sharp-tailed grouse
Common grackle
Common loon
Eared grebe
Flammulated owl
Great gray owl
Horned grebe
Long-billed curlew
Lynx
Northern goshawk
Northern pygmy-owl
Peregrine falcon
Purple martin
Red-necked grebe
Trumpeter swan
Western grebe
Wolverine

Plants:
Bulb-bearing waterhemlock
Buxbaums sedge
False mountain willow
Gray willow
Green keeled cotton-grass
Hoary willow
Pale sedge
Rush aster
Swamp willow-weed
Tweedys rush
White spruce
Yellow spring-beauty

Plant communities:
Baltic rush
Bladder sedge
Booth willow/bladder sedge
Booth willow/common horsetail
Booth willow/mesic graminoid
Buxbaums sedge
Clustered field sedge
Common cattail
Creeping spikerush
Douglas-fir/pinegrass pinegrass phase

Drummonds willow/bladder sedge
Engelmann spruce/common horsetail
Fowl bluegrass
Geyer willow/bladder sedge
Geyer willow/bluejoint reedgrass
Geyer willow/fowl bluegrass
Geyer willow/mesic graminoid
Geyer willow/water sedge
Hardstem bulrush
Inflated sedge
Kentucky bluegrass
Lodgepole pine/bluejoint reedgrass
Lodgepole pine/pinegrass
Mountain big sagebrush-mountain snowberry/Idaho fescue
Mountain big sagebrush/Idaho fescue
Nebraska sedge
Needle spike-rush
Northern mannagrass
Planeleaf willow/water sedge-bladder sedge
Pond lily
Quaking aspen-Douglas-fir/pinegrass
Quaking aspen/scoulers willow
Reed canarygrass
Short-beaked sedge
Silver sage/Kentucky bluegrass
Silver sagebrush/tufted hairgrass
Slender sedge
Subalpine fir/common snowberry
Subalpine fir/dwarf huckleberry
Subalpine fir/pinegrass
Tufted hairgrass
Valley peatland floating mat
Water ladysthumb
Water sedge
Whiplash willow/Kentucky bluegrass
White spruce/bladder sedge
White spruce/common horsetail
White spruce/softleaf sedge
Wolfs willow/bladder sedge
Wolfs willow/water sedge
Woolly sedge

GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir

Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Bitterbrush
Montane Shrub
Mountain Sage
Sagebrush Steppe
Burn_herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

Ownership: 21.4% private, 78.6% public

Possible Threats and Management Issues

- Degradation of Wetlands and Riparian Areas
- Dispersal of Invasive Weed Seed (spread by livestock)
- Operation of Dams and Reservoirs (causing fragmentation and changes in flow dynamics)
- Logging Practices (causing fragmentation, weed dispersal, and roads)
- Residential Development (in Macks Inn, Island Park, & Henry's Lake areas)
- Management of/for Migratory Antelope (halted by fencing)
- Predator Conflict (domestic sheep vs. grizzly bears)

Hoback River. (C) George Wuerthner

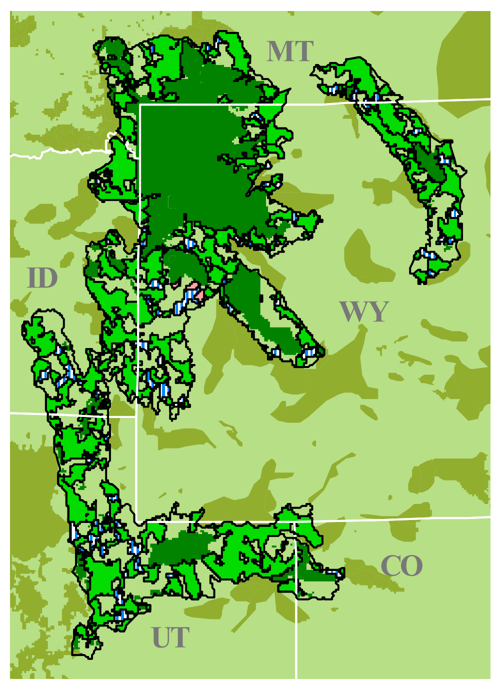
Site Name: Hoback
Size: 60,219 acres
Quadrant: 4
Irreplaceability Score: 11.3
Vulnerability Score: 23.9
Combined Score: 35.2

Site Description: The Hoback site includes the Hoback River and its upper tributaries. It borders the Gros Ventre Wilderness on the north. Other drainages include Dell Creek and Fisherman Creek. Aspen and meadowlands are common at higher elevations, along with forests of lodgepole pine and subalpine fir. The area is important habitat for moose and elk. Lynx have been reported crossing through this area.

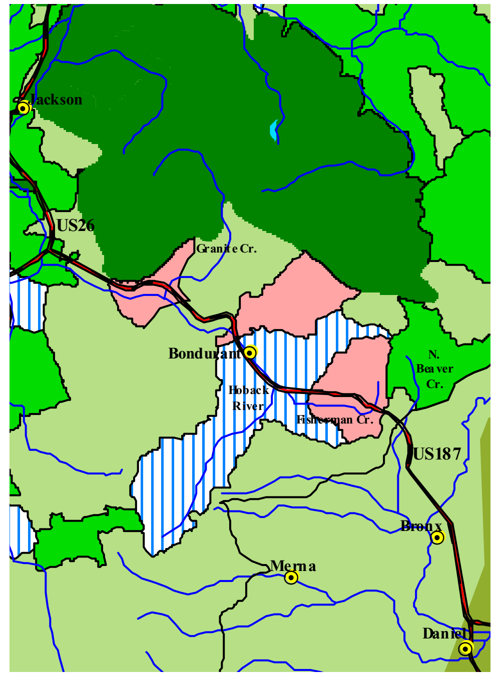
Targets List:

Plants:
Boreal draba
Creeping campion
Fragile rockbrake

GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Spruce
Aspen
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow



Barren
Lowland Riparian
Mt. Riparian
Wetland



Ownership: 8.7% private, 91.3% public

Possible Threats and Management Issues

- Conversion to Agriculture or Silviculture
- Irrigation Practices
- Improper Grazing Practices
- Residential Development
- Oil & Gas Exploration

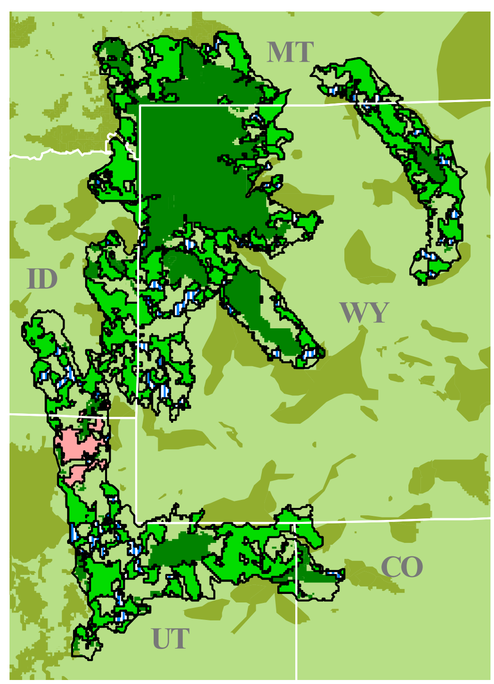
Logan at the mouth of Logan Canyon. (C) George Wuerthner

<u>Site Name</u>: Logan
<u>Size</u>: 477,824 acres
<u>Quadrant</u>: 3
<u>Irreplaceability Score</u>: 44.6
<u>Vulnerability Score</u>: 83.6
<u>Combined Score</u>:128.2

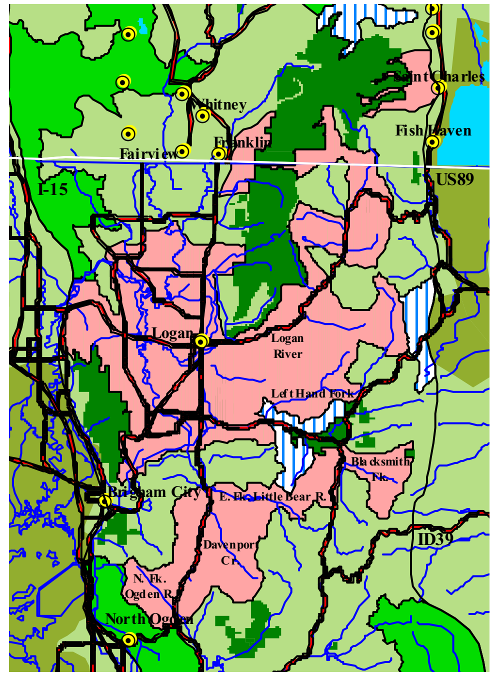
<u>Site Description</u>: The Logan site takes in the northern end of the steep western flank of the Wasatch Range and includes the Mt. Naomi Wilderness. This site lies immediately west of the Bear Lake Wyoming Basins TNC site. Drainages included in this site are South Fork of Little Bear River, Wellsville Creek, Davenport Creek, and Blacksmith Fork. The Left Hand Fork, Logan River is in the center of the site. On the northeast corner lies St. Charles Creek and on the northwest is Deep Creek and Maple Creek. The Cache Valley is included, and the Wellsville Mountains Wilderness lies along the western border. There are some significant wetlands in the Cache Valley, although much of the area has been converted to agriculture. The Wasatch Range in this area rises steeply from the valley floor, but the higher elevations are relatively rolling with some glaciated cirques and other evidence of past glaciation in higher valleys. Vegetation includes bigtooth maple, aspen, and subalpine fir with extensive meadow complexes at higher elevations. The northern end of the Wasatch Range is one of the major centers of biodiversity for mollusks in the Rocky Mountains. The flanks of the range are important for mule deer, and elk herds are growing. The steep middle reaches of the Logan River and many other streams, including the Blacksmith Fork and Left Hand Fork are hemmed in by canyon walls and, as a consequence, were not as heavily impacted by livestock as uplands or lowlands and remain as refugia for relict Bonneville cutthroat trout.

<u>Targets List</u>:

Animals:
Bonneville cutthroat trout
Flammulated owl
Fringed myotis
Gambels crayfish
Great gray owl
Green River pebblesnail
Long-eared myotis
Lyrate mountainsnail
Northern river otter
Ringneck snake
Rocky Mountain duskysnail
Sharp-tailed grouse
Snowy plover
Swamp lymnaea



Three-toed woodpecker
Toquerville springsnail
Townsends big-eared bat
Uinta chipmunk
Western red bat
Western toad



Plants:
Bear River Range beardtongue
Beckwith violet (bird-foot violet)
Cache penstemon
Cronquist daisy
Draba sp 2 (d. Burkei nom. Nov.)
Frank Smiths violet
Kings aster
Logan wild buckwheat
Maguire primrose
Maguire whitlow-grass
Rydbergs musineon
Wasatch rockcress

GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Doug Fir or White Fir
Juniper Utah
Lodgepole
Pinyon
Pinyon-Juniper
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Oak
Bitterbrush
Greasewood
Montane Shrub
Mountain Sage
Sagebrush

Sagebrush Steppe
Salt Desert Scrub
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

Ownership: 58.9% private, 41.1% public

Possible Threats and Management Issues

- Conversion to Agriculture or Silviculture
- Improper Grazing Practices (trampling of riparian zones)
- Irrigation Practices (impacting major drainages, wetlands, and springs)
- Residential Development

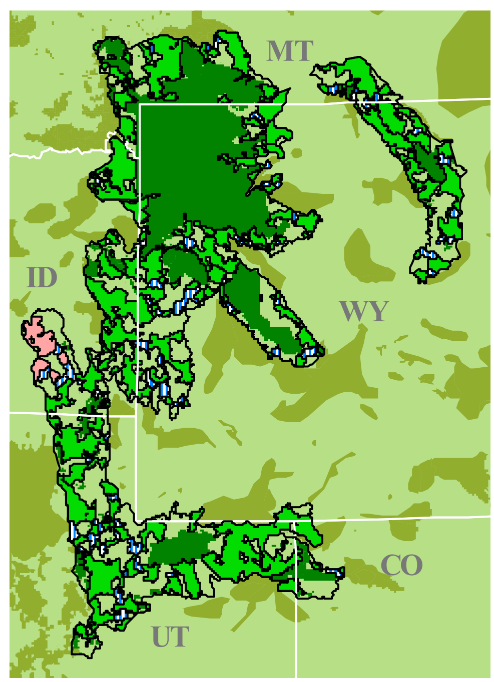
Bigtooth maple on Chink Peak. (C) George Wuerthner

Site Name: Portneuf
Size: 317,620 acres
Quadrant: 1
Irreplaceability Score: 50.8
Vulnerability Score: 61.2
Combined Score:112.0

Site Description: The Portneuf site includes portions of the Portneuf Range, southern Bannock Range, and Malad Range. Drainages included in the site are Marsh Creek, Wright Creek, Dempsey Creek, Mink Creek, Pocatello Creek, and Harness Creek. This site contains portions of a number of small mountain ranges, including the Portneuf, Bannock, Fish Creek, and Malad Ranges. A major wetlands complex exists in the Marsh Creek area. The West Fork of Mink Creek was never grazed. There are significant herds of mule deer that reside in these mountain areas, along with growing herds of elk.

Targets List:

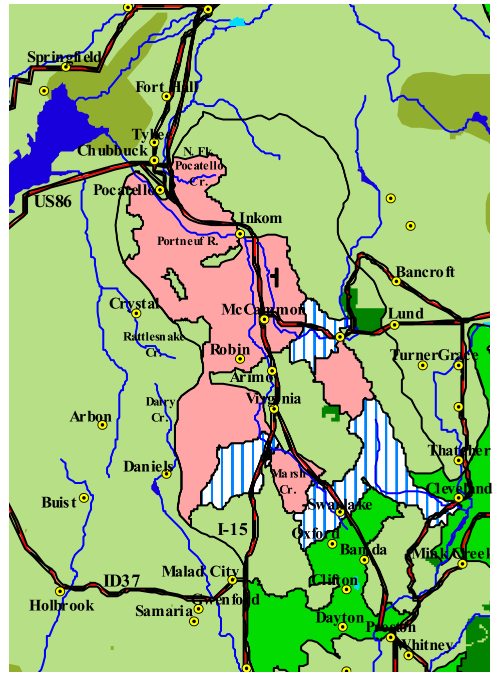
Animals:
Columbian sharp-tailed grouse
Common grackle
Flammulated owl
Great gray owl
Lesser goldfinch
Long-eared myotis
Long-legged myotis
Merriams shrew
Northern goshawk
Pinyon jay
Ringneck snake
Townsends big-eared bat
Virginias warbler
Western grebe



Plants:
Red glasswort

Plant communities:
Baltic rush
Basin big sagebrush/Great Basin wildrye
Black sagebrush/Sandbergs bluegrass
Booth willow/bladder sedge
Carex amplifolia association

Common cattail
Creeping spikerush
Douglas-fir/red-osier dogwood
Douglas-fir/pinegrass pachistima phase
Hardstem bulrush
Narrow-leaf cottonwood/water birch
Quaking aspen/red-osier dogwood
Quaking aspen/western serviceberry-mountain snowberry/pinegrass
Red-osier dogwood
Thermal springs aquatic community
Utah juniper/low sagebrush/bluebunch wheatgrass
Water birch/mesic forb
Water birch/red-osier dogwood



GAP vegetation:
Alpine Fir
Portneuf Doug Fir
Juniper Utah
Lodgepole
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Bitterbrush
Montane Shrub
Mountain Sage
Sagebrush Steppe
Dry Meadow
Grassland
Lowland Riparian
Mt. Riparian
Wetland

<u>Ownership</u>: 57.1% private, 42.9% public

<u>Possible Threats and Management Issues</u>

- Conversion to Agriculture or Silviculture
- Improper Grazing Practices
- Irrigation Practices (degrading aquatic ecosystems)
- Drainage of Wetlands (in Marsh Valley)
- Residential Development

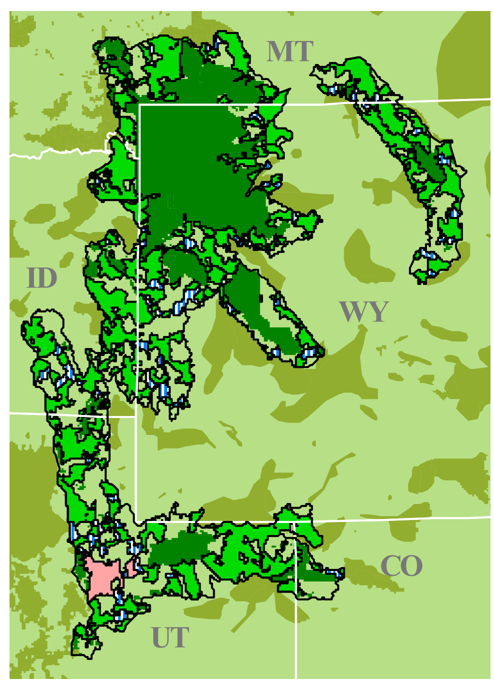
Wasatch Range near Alpine. (C) George Wuerthner

Site Name: Provo River
Size: 348,631 acres
Quadrant: 3
Irreplaceability Score: 25.5
Vulnerability Score: 68.7
Combined Score: 94.2

Site Description: The Provo River site takes in the central Wasatch Range. It borders three small wilderness areas in the Wasatch Front—Lone Peak, Mt. Olympus, and Twin Peaks. A large roadless area remains in the South Fork of the Provo drainage. Drainages within the site include Cottonwood Creek, Rock Canyon Creek, Provo River, Main Creek, South Fork Provo River, Provo-Deer Creek, American Fork River, Center Creek, Daniel's Creek, Lake Creek, and Strawberry River. The Wasatch Range is a very steep fault-block range composed primarily of sedimentary and metamorphic rocks with a few granitic outcrops. The highest peaks rise 7,000 feet above the adjacent valley to more than11,000 feet. All the higher peaks bear evidence of past glaciation in the form of cirques and U-shaped valleys. Vegetation includes Gambel's oak, bigtooth maple, aspen, and white fir. Unlike lower elevations further north, the lower elevations of the Wasatch Range are dominated by shrubs rather than grasslands, although there are plenty of subalpine meadows up higher. The flanks of the mountains were important mule deer winter range, but much of this is being taken over by housing tracts. Growing elk herds, however, may also be out-completing the deer. The Wasatch is a well known center for mollusk diversity with many of these species extirpated or very rare.

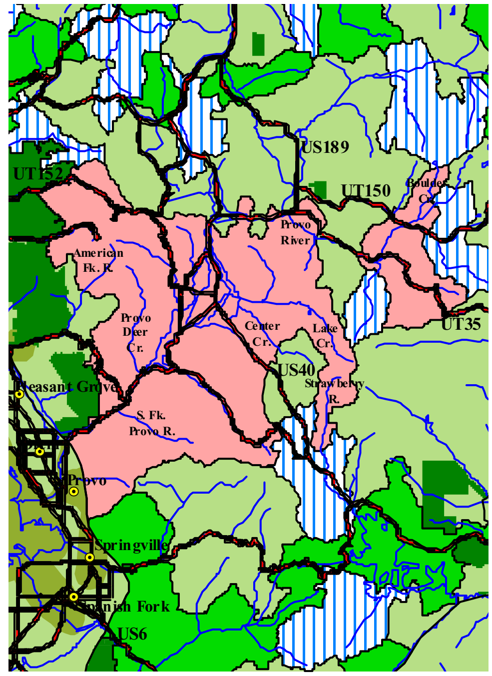
Targets List:

Animals:
Bonneville cutthroat trout
Columbia spotted frog
Fringed myotis
Leatherside chub
Northern river otter
Osprey
Three-toed woodpecker
Toquerville springsnail
Townsends big-eared bat
Western toad



Plants:
Broadleaf penstemon
Dainty moonwort
Garrett bladderpod
Garretts fleabane

Rockcress draba
Utah fleabane
Utah ivesia
Ute ladies tresses
Wasatch fitweed
Wasatch jamesia



GAP vegetation:
Alpine Fir/Spruce
Doug Fir or White Fir
Juniper Utah
Lodgepole
Lodgepole/Aspen
Pinyon
Pinyon-Juniper
Ponderosa Pine
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Oak
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian

<u>Ownership</u>: 48.6% private, 51.4% public

<u>Possible Threats and Management Issues</u>

- Residential Development (causing habitat fragmentation, dispersal of weed seed, and increase consumption of water resources)
- Conversion to Agriculture or Silviculture
- Irrigation Practices (primarily for agricultural uses)
- Recreational Infrastructure Development (ski areas along Wasatch Front)

Bull Lake Creek. (C) George Wuerthner

Site Name: Reservation
Size: 71,440 acres
Quadrant: 4
Irreplaceability Score: 27.6
Vulnerability Score: 16.4
Combined Score: 44.0

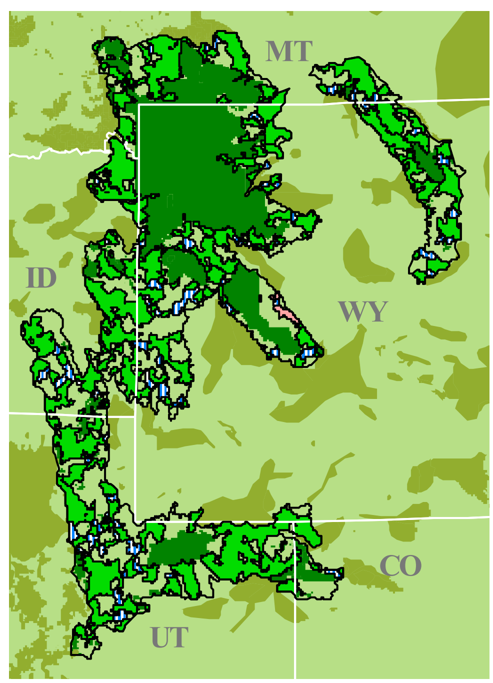
Site Description: The Reservation site lies on the eastern slope of the Wind River Range within the Wind River Indian Reservation. Starting on the south, the site includes Trout Creek, Crooked Creek, South Fork Little Wind River, Waskakie Creek, and Saint Lawrence Creek; Bull Lake Creek lies on the north end. The lower elevations are dominated by sagebrush and grasslands, while the higher mountains are cloaked in forests of lodgepole pine, subalpine fir, aspen, and whitebark pine. The very highest elevations have extensive tracts of alpine tundra. Some parts of the Wind River Valley are intensely farmed with irrigated agriculture. Wildlife is scarce in the area due to the overall low productivity of the mountains and other factors such as unregulated hunting on the reservation (which only recently changed). The changes in reservation policies have led to a growing elk herd, plus more antelope as well. Several streams, such as Bull Lake Creek harbor harlequin ducks. The Little Wind River has a population of genetically unique and pure sauger.

Targets List:

Plants:
Large yellow ladys-slipper

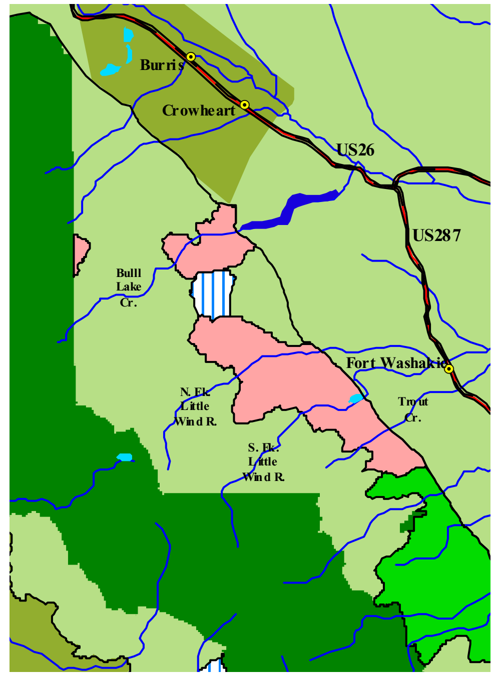
GAP vegetation:
Doug Fir
Juniper, Utah
Lodgepole
Aspen
Bitterbrush
Sagebrush
Alpine Herbaceous
Grassland

Ownership: 100% private



Possible Threats and Management Issues

- Improper Grazing Practices
- Conversion to Agriculture or Silviculture
- Irrigation Practices (water diversions)
- Oil & Gas Development
- Management of/for Big Game Populations



Rock Creek, Beartooth Mts. (C) George Wuerthner

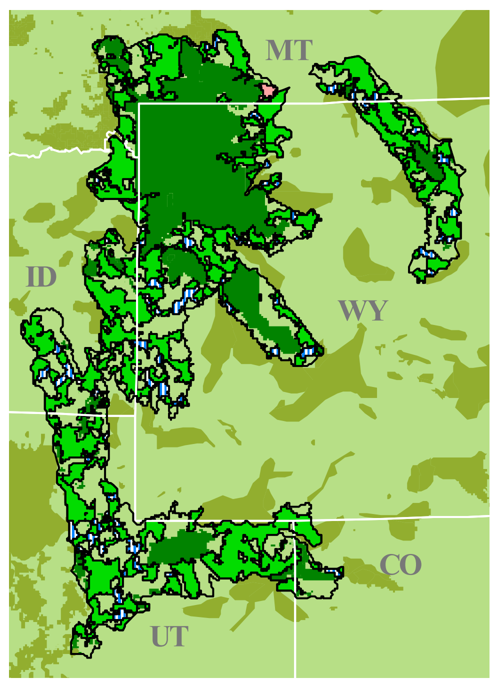
Site Name: Rock Creek
Size: 47,861 acres
Quadrant: 4
Irreplaceability Score: 18.9
Vulnerability Score: 46.3
Combined Score: 65.2

Site Description: The Rock Creek site lies on the northeast face of the Beartooth Mountains by Red Lodge, Montana. It is adjacent to the Absaroka-Beartooth Wilderness. The site includes the Line Creek Plateau as well as the upper drainage of Rock Creek and West Fork Rock Creek. The highest peaks in the range exceed 12,000 feet, and much of the range has been heavily glaciated and bears the evidence of this past sculpting, including U-shaped valleys, glacier carved lakes, and cirques. Extensive alpine plateaus harbor many arctic disjunct plant species. Relict bighorn sheep herds compete with introduced mountain goats for habitat at the higher elevations. Several small elk herds roam the fringes between the mountains and adjacent ranchlands.

Targets List:

Plants:
Paludella squarrosa
Beartooth large-flowered goldenweed
Clasping groundsel
Porsilds draba

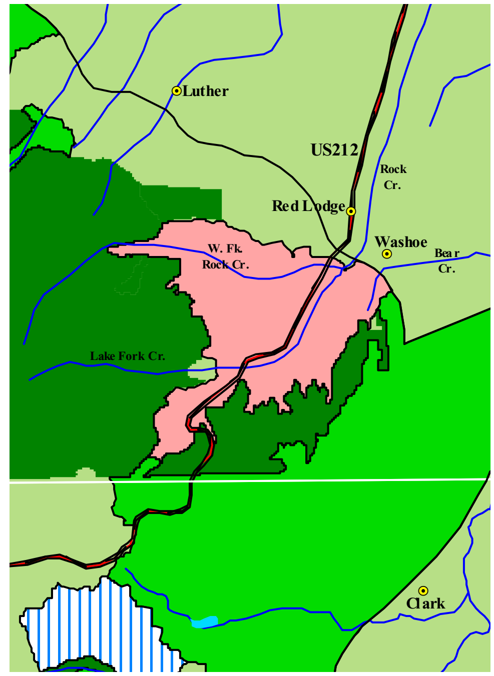
GAP vegetation:
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Pinyon-Juniper
Whitebark/Limber Pine
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland



Ownership: 15.9% private, 84.1% public

Possible Threats and Management Issues

- Irrigation Practices
- Improper Grazing Practices
- Predator Control
- Residential Development (namely in Red Lodge)
- Past Oil & Gas Exploration



Sagebrush flat, Southern Big Horn Mountains. (C) George Wuerthner

Site Name: South Bighorns
Size: 99,998 acres
Quadrant: 4
Irreplaceability Score: 23.5
Vulnerability Score: 23.9
Combined Score: 47.4

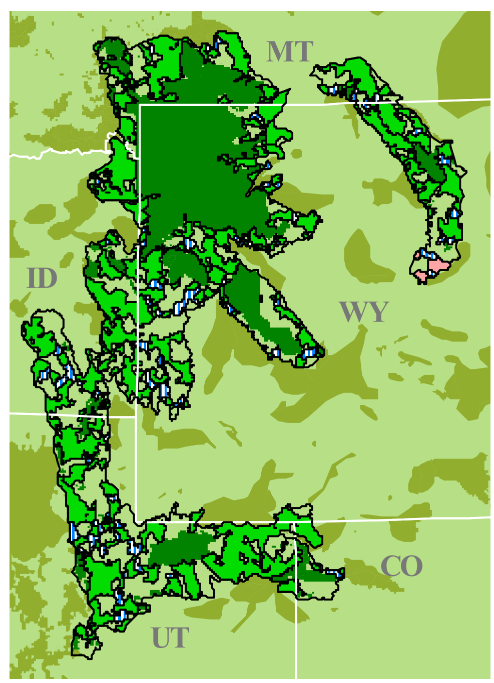
Site Description: The South Bighorns site takes in the southern end of the Bighorn Mountains. These mountains rise abruptly from the adjacent lowlands. The lower slopes, particularly on the west side, appear similar to southern Utah, with sedimentary badlands covered with juniper. Not nearly as high as other parts of the range, most of the peaks are under 9,000 feet. There are three disjunct units in the site. The area borders a site in TNC's Wyoming Basin's portfolio. The site includes Badwater Creek, Bear Creek in the northern unit, and North Fork Buffalo Creek. This is a very remote area. Antelope and mule deer are the most abundant larger mammals.

Targets List:

Plants:
Daggett rock cress
Williams spring-parsley

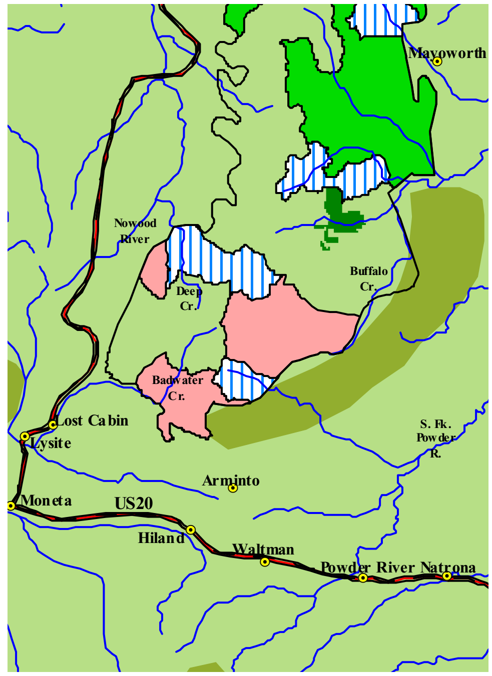
GAP vegetation:
Doug Fir
Juniper Utah
Ponderosa Pine
Whitebark/Limber Pine
Mountain Sage
Sagebrush
Salt Desert Scrub
Grassland
Barren
Mt. Riparian

Ownership: 47.8% private, 52.2% public



Possible Threats and Management Issues

- Disease Transmission (from sheep to Big Horns)
- Irrigation Practices
- Improper Grazing Practices
- Development by Energy Companies



Aspen along Tincup Creek, Caribou Mts.
(C) George Wuerthner

Site Name: South Caribou Mountains-Gray's Lake
Size: 392,377 acres
Quadrant: 1
Irreplaceability Score: 75.8
Vulnerability Score: 53.7
Combined Score: 129.5

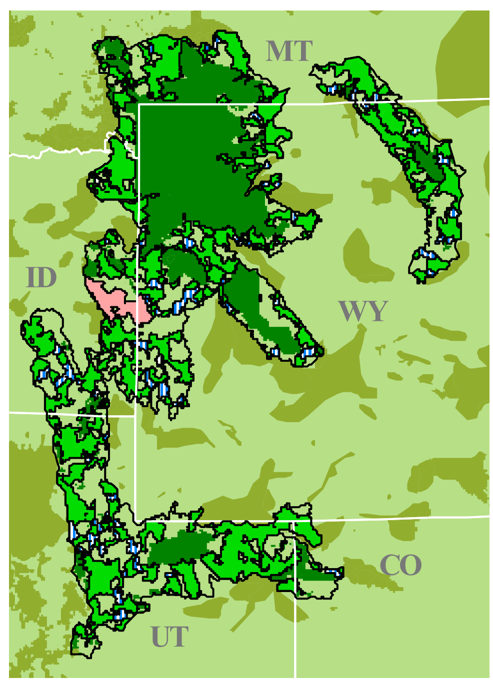
Site Description: This site includes Gray's Lake Wildlife Refuge and the southern part of the Caribou Mountains. It borders a TNC portfolio site on the west. The Caribou Mountains consist of parallel ridges dissected by stream valleys. Drainages in this site include Tincup Creek, Deep Creek, Jackknife Creek, McCoy Creek, Brockman Creek, Gray's Lake outlet, and Homer Creek. The area has extensive wetlands. In addition, the Caribou Mountains are among the wettest ranges in southeast Idaho. The area boasts extensive aspen groves, willow-lined riparian areas, and lush flowery meadows. The Caribou Mountains contain some of the best elk habitat and highest density of elk in southeast Idaho, plus growing numbers of moose. Sandhill cranes are abundant in the Gray's Lake area.

Targets List:

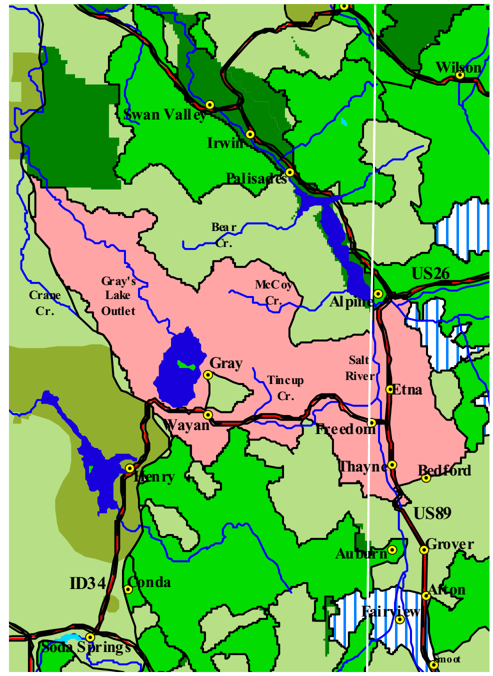
Animals:
Bald eagle
Black tern
Eared grebe
Forsters tern
Franklins gull
Lark bunting
Long-billed curlew
Peregrine falcon
Trumpeter swan
White-faced ibis
Whooping crane

Plants:
Paysons bladderpod

Plant communities:
Akali cordgrass
Baltic rush
Bebb willow
Bladder sedge
Booth willow/mesic graminoid
Common cattail



Creeping spikerush
Engelmann spruce/red-osier dogwood
Geyer willow/mesic graminoid
Hardstem bulrush
Mat muhly
Nebraska sedge
Needle spike-rush
Pond lily
Short-beaked sedge
Silver sage/Kentucky bluegrass
Slender sedge
Tufted hairgrass



GAP vegetation:
Alpine Fir
S. Caribou Mtns/Gray's Lake Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Maple
Bitterbrush
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

<u>Ownership</u>: 49.3% private, 50.7% public

<u>Possible Threats and Management Issues</u>

- Livestock Production Practices (degraded riparian zone)
- Dispersal of Exotic Weeds

- Irrigation Practices
- Drainage of Wetlands
- Conversion to Agriculture or Silviculture
- Logging Practices (causing habitat fragmentation & road development)
- Oil & Gas Exploration

Palisades roadless area. (C) George Wuerthner

Site Name: South Fork Snake
Size: 222,651 acres
Quadrant: 3
Irreplaceability Score: 19.6
Vulnerability Score:68.7
Combined Score: 88.3

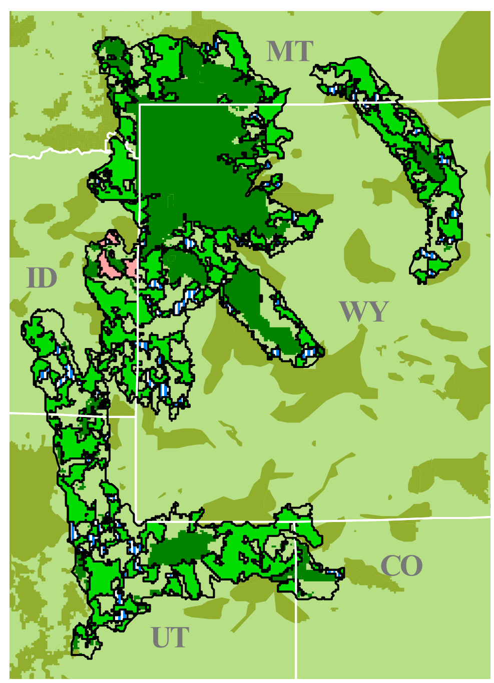
Site Description: The South Fork of the Snake River lies at the center of this site, which includes a protected area straddling both sides of the river and taking in the Big Hole Mountains, Palisades area north of the river, and the north end of the Caribou Mountains south of the river. Extensive roadless areas in the three mountain areas of the site are proposed for wilderness designation. This site borders a TNC portfolio site on the northern border. Drainages include Big Elk and Palisades Creek in Snake Range, Fall Creek and Antelope Creek in the Caribou Mountains, and Canyon Creek in the Big Hole Mountains. The area supports heavy aspen growth plus extensive meadows. Conifer forests consist of lodgepole pine, Douglas-fir, and subalpine fir. The South Fork of the Snake is one of the major bald eagle winter roost sites in Idaho. Elk, moose, mule deer, and a growing population of exotic mountain goats (in the Palisades) are found here, plus the densest populations of black bear in southeast Idaho. This could be one of the most suitable areas of Southeast Idaho for grizzly bear and wolf recolonization. Several tributaries of the South Fork harbor genetically pure Yellowstone cutthroat trout populations. The cottonwood forests along the South Fork of the Snake are important habitat for neotropical migrants, as well as one of the densest nesting populations of bald eagles in the ecosystem.

Targets List:

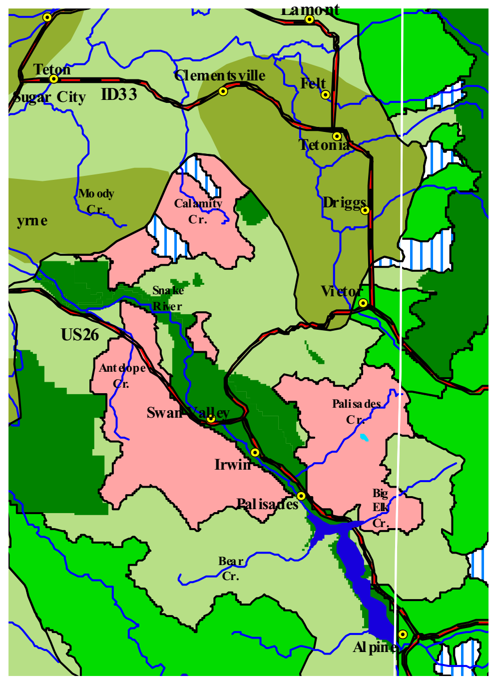
Animals:
Bald eagle
Barrows goldeneye
Common goldeneye
Flammulated owl
Great gray owl
Northern goshawk
Peregrine falcon

Plants:
Gray willow
Paysons bladderpod

Plant communities:
Coyote willow/mesic forb
Douglas-fir/mountain maple
Douglas-fir/white spiraea



Mountain big sagebrush/bluebunch wheatgrass
Narrow leaf cottonwood/Kentucky bluegrass
Narrowleaf cottonwood/red-osier dogwood
Red-osier dogwood
Water birch/red-osier dogwood



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Lodgepole
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Mountain Mahogany
Bitterbrush
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Barren
Lowland Riparian
Mt. Riparian

Ownership: 17.6% private, 82.4% public

Possible Threats and Management Issues

- Irrigation Practices
- Dispersal of Exotic Weeds
- Improper Grazing Practices
- Oil & Gas Exploration and Drilling (Overthrust Belt – high in hydrocarbons)
- Residential Development

Tributary of Yellowstone River, south flank of Uinta Mts. (C) George Wuerthner

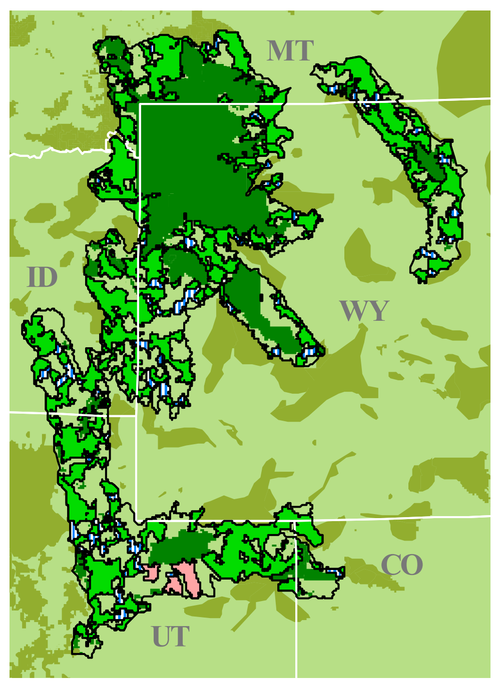
Site Name: South Uintas
Size: 272,142 acres
Quadrant: 1
Irreplaceability Score: 78.4
Vulnerability Score: 68.7
Combined Score: 147.1

Site Description: The South Uintas site lies on the southern flank of the Unita Range and borders the High Unita Wilderness on the north. As one of the only major mountain uplifts that are oriented east-west, the Uintas are ideally located to pick up substantial amounts of snowfall in winter. In addition, monsoonal thunderstorm tracks from the Gulf of Mexico reach this area frequently during the summers, contributing to abundant summer moisture. Hence, the Uintas are the wettest range in Utah with more than 2000 lakes, acting as the headwaters for many of the state's rivers. Drainages in this site include Lake Fork River and its tributary, the Yellowstone River, Rock Creek, Duchesne River, West Fork Duchesne, and North Fork Duchesne. Vegetation spans low elevation arid sagebrush and greasewood flats up to aspen groves and rich, lush meadows to alpine tundra on some of the higher peaks. Mule deer is the most abundant large mammal, though elk numbers are growing. The Uintas are considered by many biologists to be the best location in the state for both grizzly bear and wolf restoration.

Targets List:

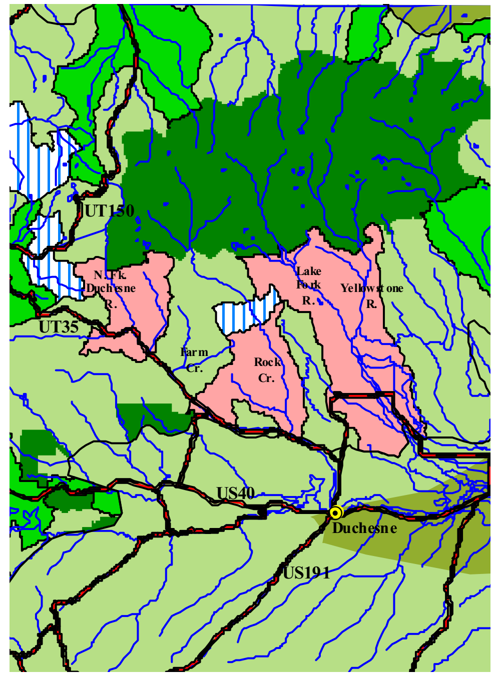
Animals:
Colorado River cutthroat trout
Nokomis fritillary

Plants:
Canyon sweetvetch
Few-leaflet cinquefoil
Fibrous pondweed
Green spleenwort
Murdocks thistle
Petiolate wormwood
Rockcress draba
Showy pussytoes
Uintah beardtongue
Ute ladies tresses
Wasatch draba



GAP vegetation:
Alpine Fir/Spruce
Doug Fir or White Fir

Juniper Utah
Lodgepole
Lodgepole/Aspen
Pinyon
Pinyon-Juniper
Ponderosa Pine
Aspen
Aspen/Conifer
Mountain Mahogany
Oak
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Salt Desert Scrub
Alpine Herbaceous
Desert Grassland
Dry Meadow
Grassland
Wet Meadow
Barren



Ownership: 65.5% private, 34.5% public

Possible Threats and Management Issues

- Improper Grazing Practices
- Irrigation Practices
- Construction of Reservoirs
- Energy Development (roads, weed dispersal, and habitat fragmentation)
- Logging Practices (forest fragmentation)

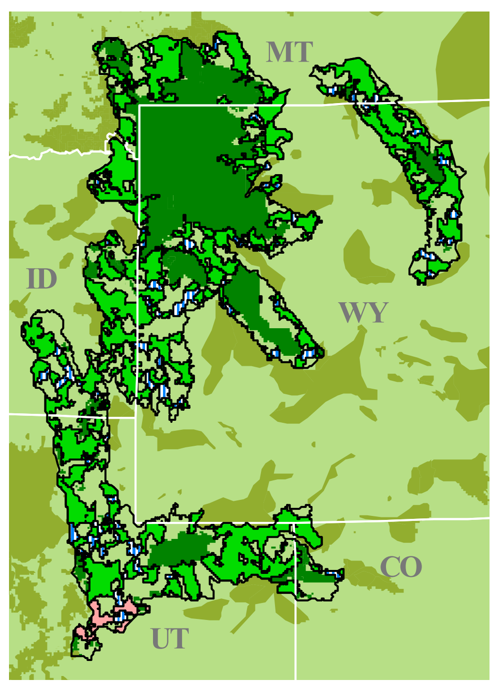
South Wasatch Range. (C) George Wuerthner

Site Name: South Wasatch
Size: 255,852 acres
Quadrant: 3
Irreplaceability Score: 48.1
Vulnerability Score: 98.5
Combined Score: 146.6

Site Description: The Wasatch Range rises dramatically along a major fault. The higher elevations were heavily glaciated, giving the entire range a rugged and dramatic aspect. The South Wastach site includes the Mt. Timpanogos Wilderness and Mt. Nebo Wilderness, as well as the highest peaks in the range, with Mt. Nebo rising to nearly 12,000 feet. The site borders several cities, including Spanish Fork, Payson, and Santaquin. Beginning in the south is Thistle Creek, Peteetneet Creek, Spanish Fork, Diamond Fork, Hobble Creek, Soldier Creek, Sixth Water Creek, and Tie Fork Soldier Creek. The lower elevations are dominated by Gambel's oak and bigtooth maple with some Douglas-fir. Higher forests include aspen, white fir, and occasional limber pine. The Mt. Nebo area harbors one of Utah's largest elk herds, and mule deer are abundant throughout the area. There are a variety of mollusk species found throughout the Wasatch Range, many of them rare or endangered.

Targets List:

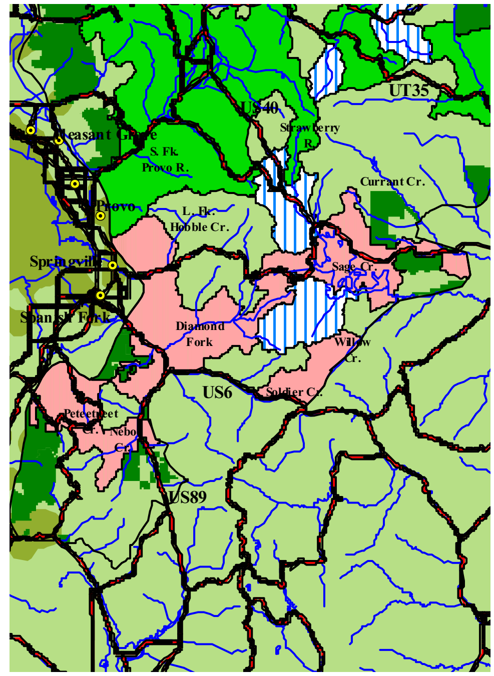
Animals:
Bonneville cutthroat trout
Northern river otter
Paiute sculpin
Peregrine falcon
Smooth green snake
Southern bonneville springsnail
Toquerville springsnail



Plants:
Dragon milkvetch
Garrett bladderpod
One-flower wintergreen
Physaria acutifolia var *purpurea*
Repand twinpod
Skyline townsendia
Ute ladies tresses

GAP vegetation:
Alpine Fir/Spruce
Doug Fir or White Fir

Juniper Utah
Lodgepole
Pinyon
Pinyon-Juniper
Ponderosa Pine
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Oak
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian



Ownership: 24.6% private, 75.4% public

Possible Threats and Management Issues

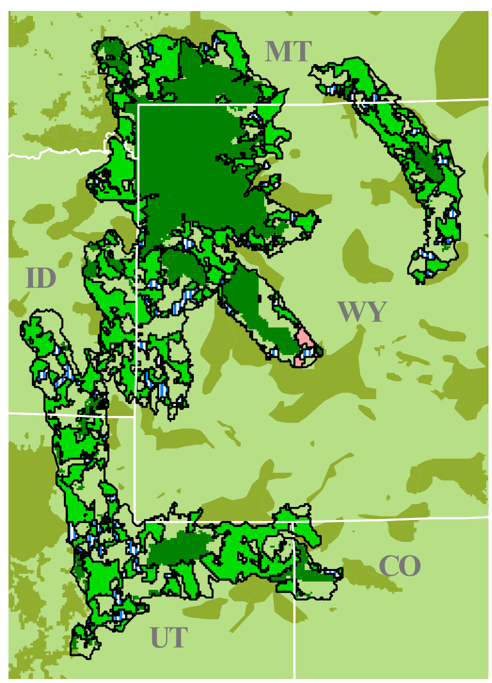
- ■ Residential Development (very high population density)
- ■ Recreational Infrastructure Development (ski areas)
- ■ Conversion to Agriculture or Silviculture
- ■ Irrigation Practices (primarily agricultural)
- ■ Operation of Dams on Streams
- * Rated highest in vulnerability (with Wasatch Front) of all megasites.

Antelope near southern end of Wind River Range. (C) George Wuerthner

Popo Agie River, Sinks Canyon. (C) George Wuerthner

Site Name: South Winds
Size: 107,554 acres
Quadrant: 3
Irreplaceability Score: 23.7
Vulnerability Score: 61.2
Combined Score: 84.9

Site Description: The South Winds site includes the southern end of the Wind River Range. The core of the range is granitic, but sedimentary rocks flank the range, including limestone and sandstones. These rocks are steeply inclined and almost ramp-like, as they have been uplifted with the rising of the range. The higher elevations are heavily glaciated, with numerous small lakes and glacial cirques. The core of the range is protected in the Popo Agie and Bridger Wilderness areas, plus TNC's Red Canyon Ranch covers a portion of the flank near Lander. The Big Sandy River is in the most westerly unit, while other units contain the East Sweetwater River, Mill Creek, Little Sweetwater River, Cherry Creek by Red Canyon Ranch, Willow Creek, Crooked Creek, Popo Agie River, Little Popo Agie River, Middle Popo Agie. South Fork Squaw Creek, Baldwin Creek, and North Fork Popo Agie River on the northeast. The southern Winds serve as important migration pathways for wildlife coming off the Wind River Range or moving out into the Red Desert from both the Wind and Green River valleys. The area supports large mule deer herds, plus elk and abundant antelope. There are some relict bighorn sheep herds, including one in Sinks Canyon. Several rare plant species are recorded on the sedimentary strata that flank the range.

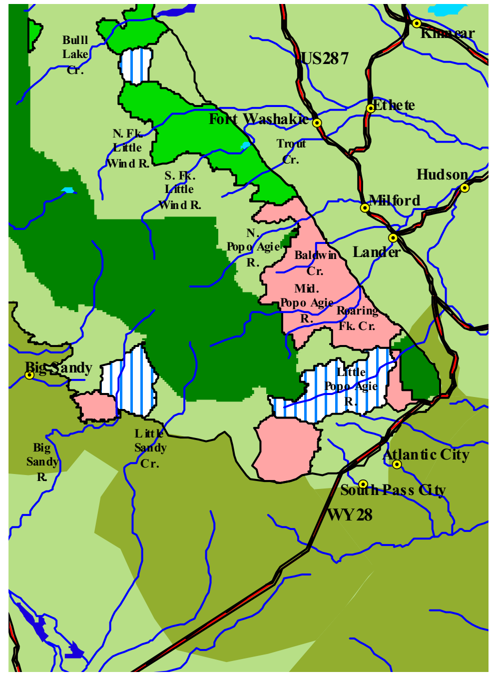


Targets List:

Animals:
Northern leopard frog
Yellowstone cutthroat trout

Plants:
Daggett rock cress
Fremont bladderpod

Rocky Mountain twinpod

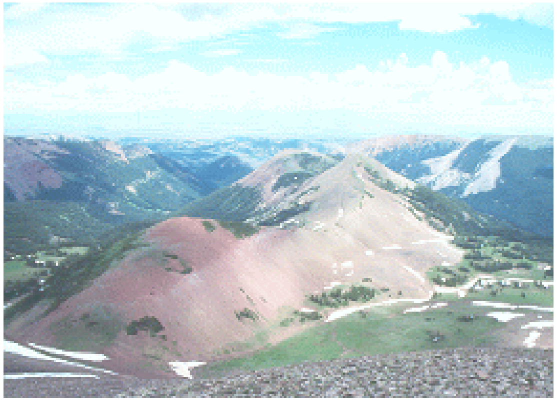


GAP vegetation:
Alpine Fir
Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Juniper Utah
Lodgepole
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Bitterbrush
Burn Shrub
Montane Shrub
Mountain Sage
Sagebrush
Alpine Herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Barren
Mt. Riparian

Ownership: 20.1% private, 79.9% public

Possible Threats and Management Issues

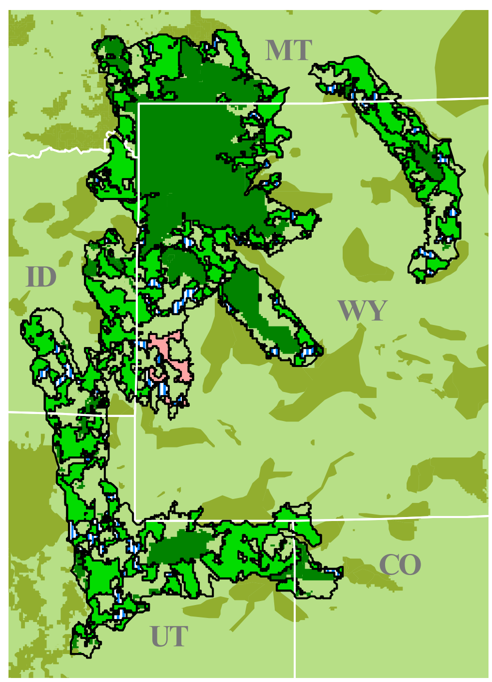
- Improper Grazing Practices
- Disease Transmission to Native Big Horns
- Irrigation Practices (dewatering of streams)
- Conversion to Agriculture or Silviculture
- Groundwater Manipulation (use of springs)
- Residential Development



Piney Creek drainage from Wyoming Peak, Wyoming Range. (C) George Wuerthner

Site Name: South Wyoming Range
Size: 301,036 acres
Quadrant: 3
Irreplaceability Score: 40.9
Vulnerability Score: 91.0
Combined Score: 131.9

Site Description: The South Wyoming Range site includes its namesake, the South Wyoming Range, the southern end of the Salt River Range, as well as Commissary Ridge. This is part of the Overthrust Belt, a major petroleum-bearing geological formation. Its southern border lies just north of Kemmerer, Wyoming. Drainages in the site include Fontenelle Creek on the southeast side, Beaver Creek on the southwest corner, Dry Piney Creek along the eastern face, South Piney Creek, Middle Creek, Hobble Creek, Smiths Fork, Upper Grey's River, South Cottonwood Creek on the northeast corner, and Dry Creek and Swift Creek on the northwest corner. Extensive areas of sagebrush and meadows are common throughout the area, with aspen, lodgepole pine, Engelmann spruce, and subalpine forest in pockets at higher elevations. The area is a major big game region with large herds of elk, mule deer, moose, and antelope. Colorado cutthroat trout are found in streams draining to the Green River, and Bonneville cutthroat trout are found in the Smiths Fork. This area contains some of the best moose habitat in Wyoming. Recent sightings and control actions on wolves confirm that the area is being colonized by these animals. There are also lynx and wolverine reported for the area. Based primarily on habitat factors, the area also has tremendous potential for grizzly bear restoration.

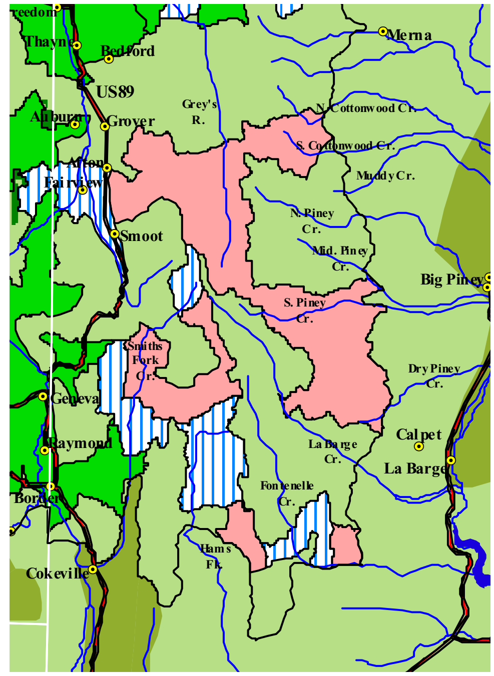


Targets List:

Animals:
Colorado River cutthroat trout
Fine-spotted Snake River cutthroat
Leatherside chub
Western boreal toad

Plants:
Aromatic pussytoes
Big piney milkvetch
Boreal draba
Compact gilia
Paysons bladderpod
Paysons milkvetch
Shultzs milk-vetch
Taprooted fleabane

Plant communities:
Fearnleaf wild lovage-dunce-cap larkspur



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Mountain Mahogany
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Burn_herbaceous
Dry Meadow
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Mt. Riparian

Ownership: 8.2% private, 91.8% public

Possible Threats and Management Issues

- Energy Development (Overthrust Belt)
- Improper Grazing Practices (primarily by sheep)
- Predator Control (particularly wolves)
- Conversion to Agriculture or Silviculture
- Irrigation Practices

Gallatin River. (C) George Wuerthner

Site Name: Spanish Peak Additions
Size: 129,715 acres
Quadrant: 1
Irreplaceability Score: 65.4
Vulnerability Score: 68.7
Combined Score: 134.1

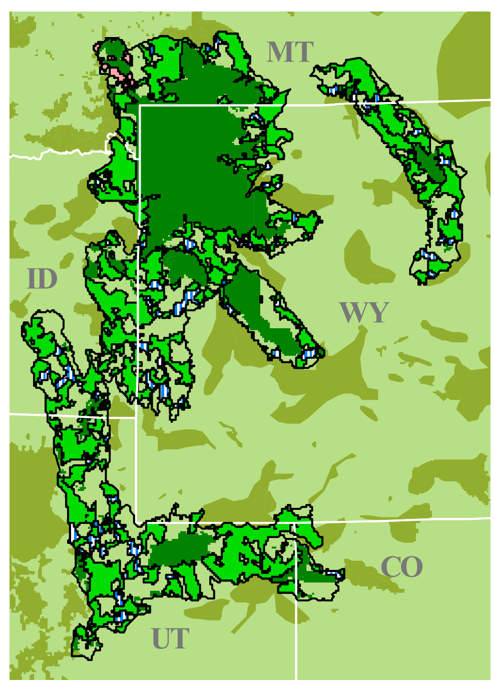
Site Description: The Spanish Peaks Additions site comprises nine pieces that surround the Spanish Peaks unit and the Beartrap unit of the Lee Metcalf Wilderness, plus Ted Turner's Flying D Ranch. The site also lies adjacent or in close proximity to several sites in TNC's Middle Rockies portfolio. The Spanish Peaks are high, glaciated granitic peaks that are part of the Lee Metcalf Wilderness. The area is isolated from the rest of the wilderness by development in the Big Sky area. The site includes the West Fork of the Gallatin River, where Big Sky Resort is located, Jack Creek that drains into the Madison River, Bradley Creek, and the Gallatin River on the eastern border of the site. Elk, mule deer, and black bear are found in the area, as well as occasional grizzly bear. There are plans to restore westslope cutthroat trout to Cherry Creek on the Flying D Ranch.

Targets List:

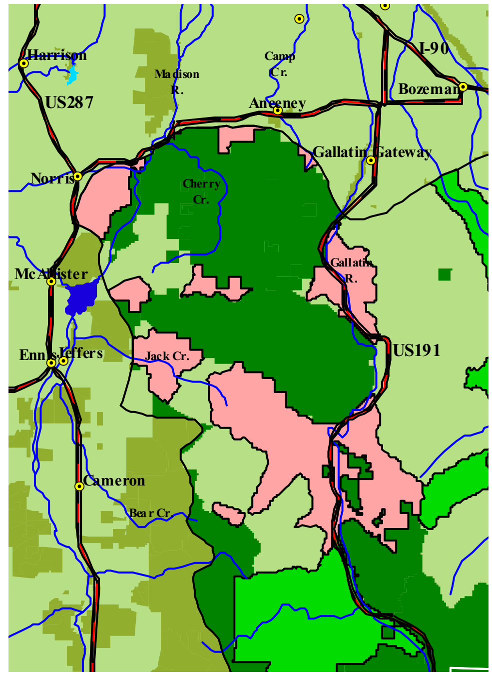
Animals:
Boreal owl
Peregrine falcon

Plants:
Musk-root
Slender indian paintbrush

GAP vegetation:
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Western
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Whitebark/Limber Pine
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Alpine Herbaceous
Grassland



Wet Meadow
Barren
Mt. Riparian
Wetland



Ownership: 52.1% private, 47.9% public

Possible Threats and Management Issues

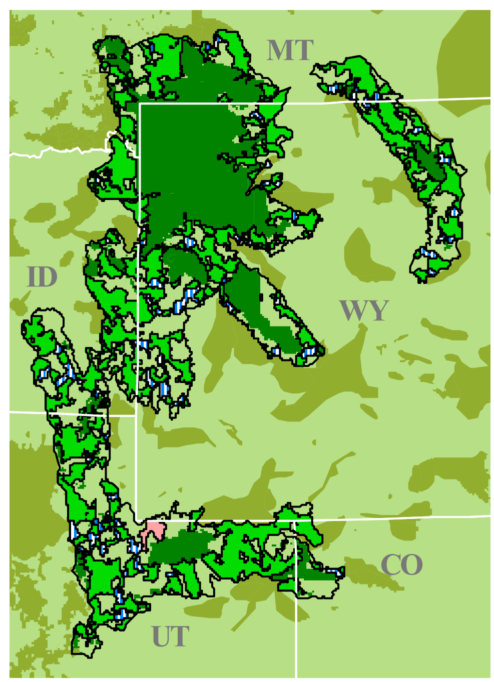
- Recreational Infrastructure Development
- Road Development
- Past Heavily Logged
- Large Logging Road Network (fragmentation)

Uinta Mountains: headwaters of Bear River.

Site Name: Upper Bear
Size: 113,000 acres
Quadrant: 3
Irreplaceability Score: 35.2
Vulnerability Score: 83.6
Combined Score:118.8

Site Description: The Upper Bear site takes in the headwaters of the Bear River on the northern flanks of the Uinta Range. It is bordered on the south by the High Uintas Wilderness. Major unprotected roadless areas, including the northern fringe of the High Uintas Wilderness and on the Mirror Lake Plateau, could be added to the wilderness system. The Uintas rise to over 13,000 feet and are well-watered with thousands of lakes and the headwaters of numerous rivers. The southern end of this site includes the upper headwaters of the Weber River along with Dry Fork. Tributaries of the Bear River include Mill Creek, East Fork Bear River, Stillwater Fork Bear River, and Deer Creek. Though mostly in Utah, the site overlaps slightly into Wyoming. Vegetation consists of abundant aspen and extensive lodgepole pine forests. Subalpine meadows are abundant, and there are extensive areas of alpine tundra. The site harbors some of the largest moose populations in Utah, plus elk, mule deer, and black bear. Habitat exists for the extirpated wolf and grizzly bear, while sightings of lynx and wolverine are still reported. A diversity of rare mollusks is reported for this area.

Targets List:

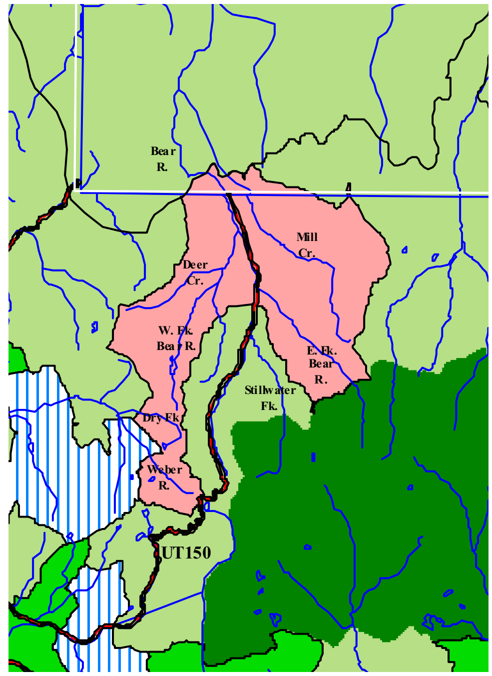


Animals:
Bonneville cutthroat trout
Lynx
Three-toed woodpecker
Western toad

Plants:
Robbins milkvetch
Utah ivesia

GAP vegetation:
Alpine Fir/Spruce
Doug Fir or White Fir
Lodgepole
Lodgepole/Aspen
Pinyon
Pinyon-Juniper
Ponderosa Pine
Aspen

Aspen/Conifer
Oak
Montane Shrub
Mountain Sage
Sagebrush
Alpine Herbaceous
Dry Meadow
Grassland
Wet Meadow
Barren
Mt. Riparian



<u>Ownership</u>: 27.4% private, 72.6% public

<u>Possible Threats and Management Issues</u>

- Improper Grazing Practices
- Irrigation Practices
- Recreational Infrastructure Development
- Residential Development
- Logging Practices (fragmentation and new roads)
- Energy Development (along north slope of Uintas)

Daisy Pass near Cooke City. (C) George Wuerthner

Site Name: Upper Clark Fork
Size:18,332
Quadrant: 4
Irreplaceability Score: 25.9
Vulnerability Score: 1.5
Combined Score: 27.4

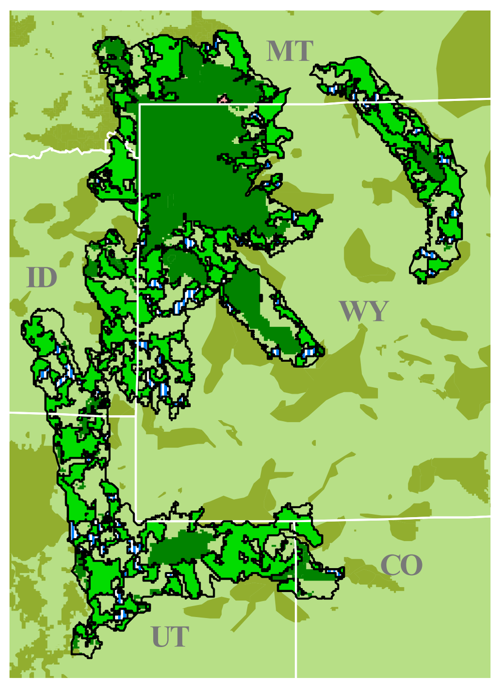
Site Description: This site includes the headwaters of the Clark Fork River in Montana near Cooke City. Drainages in the site include Soda Butte Creek and Fisher Creek. The area has been heavily glaciated and is mineralized, spurring mining activity for more than a century. The area is home to wolves, grizzly bears, bighorn sheep, and moose. The forests consist of lodgepole pine and Engelmann spruce, with whitebark pine at higher elevations. Alpine tundra occurs on the highest peaks. Reclamation of past mining activities is ongoing.

Targets List:

Plants:
Slender Indian paintbrush
Wolfs willow

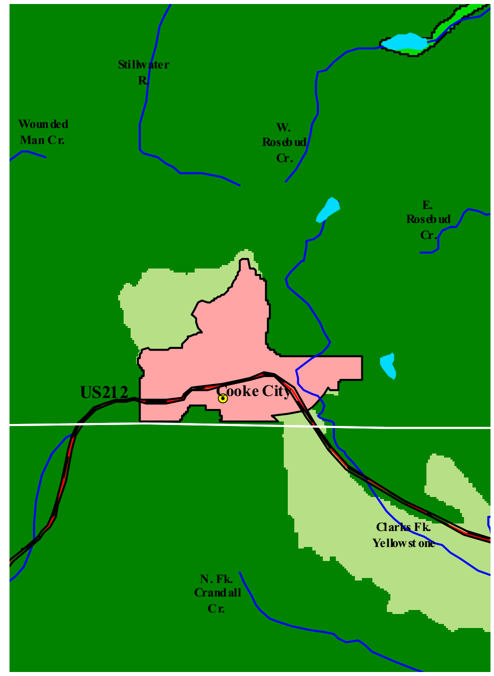
GAP vegetation:
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Pinyon-Juniper
Whitebark/Limber Pine
Burn_Shrub
Montane Shrub
Mountain Sage
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

Ownership: 16.7% private, 83.3% public



<u>Possible Threats and Management Issues</u>

- Residential Development
- Improper Grazing Practices
- Predator Control Practices
- Past Logging Practices (road networks)



Headwaters of Wapiti Creek, Madison Range. (C) George Wuerthner

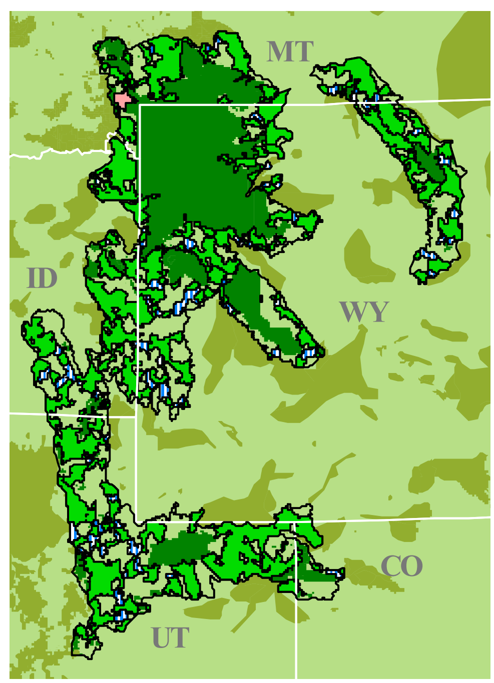
Site Name: Upper Gallatin
Size: 69,249 acres
Quadrant: 4
Irreplaceability Score: 35.7
Vulnerability Score: 9.0
Combined Score: 44.7

Site Description: The Upper Gallatin site lies adjacent to the Lee Metcalf Wilderness in the Madison Range. The Madison Range contains the second highest peaks in Montana and has both heavily glaciated, barren peaks as well as rich subalpine meadows. The site includes the Taylor Fork and tributaries Wapiti Creek and Sage Creek. This area has one of the highest levels of use by grizzly bears in the ecoregion. In addition, several resident wolf packs occupy the area. Elk and moose are abundant. Wolverine, lynx, and marten are all recorded. The upper Gallatin River is a Montana grayling restoration site. There is some unprotected roadless land in the area that could be added to the wilderness.

Targets List:

Plants:
Discoid goldenweed
Large-leafed balsamroot
Slender Indian paintbrush
Wolfs willow

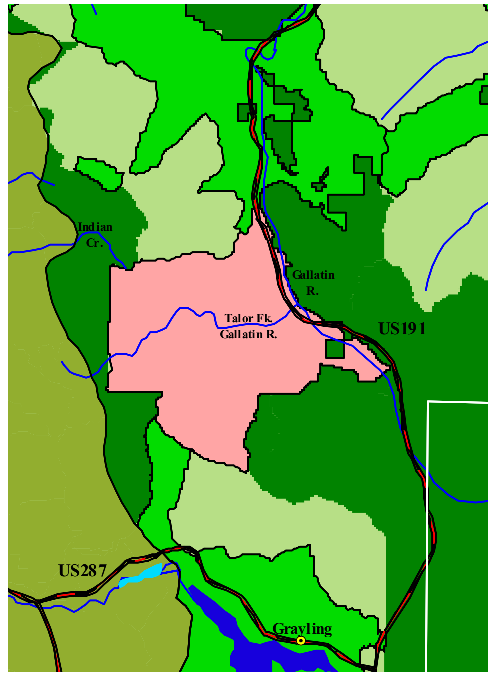
GAP vegetation:
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Western
Lodgepole
Pinyon-Juniper
Whitebark/Limber Pine
Aspen/Conifer
Mountain Sage
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland



Ownership: 18.8% private, 81.2% public

Possible Threats and Management Issues

- Heavy Road Use (road kill, especially of wolves)
- Habitat Fragmentation from Roads and Clearcuts



Upper Green River. (C) George Wuerthner

Site Name: Upper Green
Size: 127,044 acres
Quadrant: 1
Irreplaceability Score: 92.1
Vulnerability Score: 53.7
Combined Score: 145.8

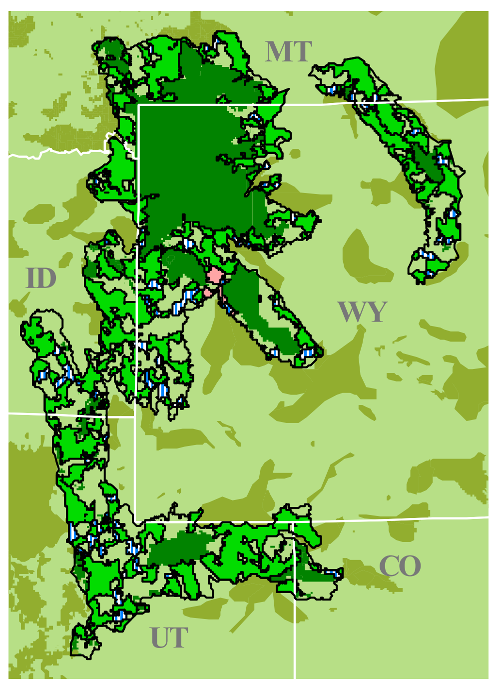
Site Description: The Upper Green site includes the Upper Green River drainage and lies between the Gros Ventre Wilderness on the northwest and Bridger Wilderness on the northeast. Drainages in the site include Faler creek, New Fork River, Boulder Creek, Pot Creek, and Gypson Creek, all on the western slope of the Wind River Range. In the north are Wagon Creek, Tosi Creek, Tepee Creek, Big Twin, and Little Twin on the northwest flowing out of the Gros Ventres. On the south, the site borders TNC's Green River site in the Wyoming Basins portfolio. The Upper Green is a major big game migration corridor with antelope, elk, and mule deer all funneling through this area in spring and fall. There is also a significant moose population. The Kendall Warm Springs dace is also found in a single spring in the upper valley.

Targets List:

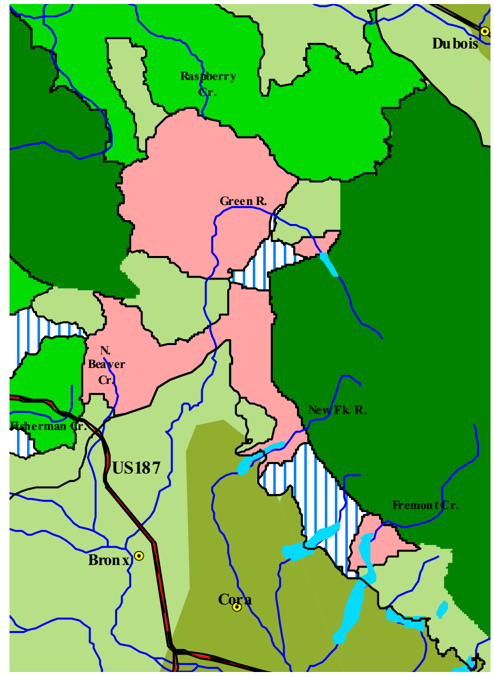
Animals:
Bald eagle
Colorado River cutthroat trout
Flannelmouth sucker
Kendall Warm Springs dace
Northern goshawk
Peregrine falcon
Trumpeter swan
Western boreal toad
Western screech owl

Plants:
False uncinia sedge
Greenland primrose
Narrowleaf goldenweed
Paysons bladderpod

GAP vegetation:
Alpine Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Lodgepole



Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Montane Shrub
Mountain Sage
Alpine Herbaceous
Dry Meadow
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland



<u>Ownership</u>: 5.3% private, 94.7% public

<u>Possible Threats and Management Issues</u>

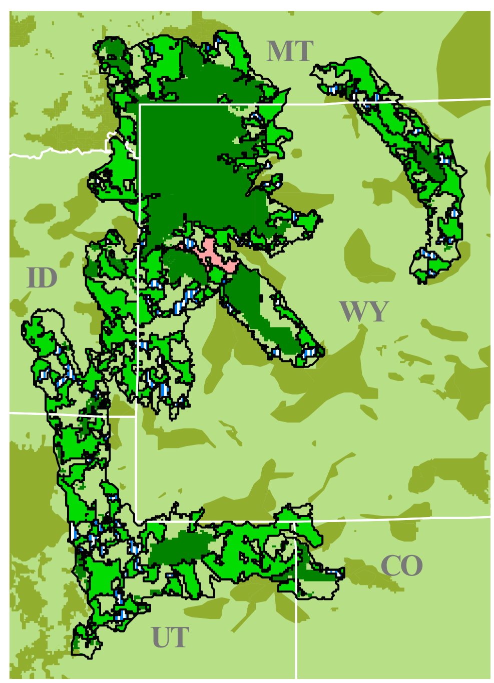
- Improper Grazing Practices
- Residential Development
- Energy Development

Upper Gros Ventre River. (C) George Wuerthner

Site Name: Upper Gros Ventre
Size: 214,156 acres
Quadrant: 2
Irreplaceability Score: 90.1
Vulnerability Score: 38.8
Combined Score: 128.9

Site Description: The Upper Gros Ventre site lies just north of the Gros Ventre Wilderness. It includes the Upper Gros Ventre River drainage. The Mount Leidy Highlands are to the north, while the Gros Ventre Mountains lie to the south. Other streams in the site include Little Warm Spring Creek, Spruce Creek, and South Fork of Warm Spring Creek, which flow into the upper Wind River, plus South Fork Fish Creek, Park Creek, Leeds Creek, North Fork Fish Creek, Cottonwood Creek, Bacon Creek, and Horsetail Creek near Slide Lake. The Gros Ventre River is one of the most northern areas for blue spruce in the area. Aspen and open sagebrush-grasslands are abundant at lower elevations. Lodgepole pine, Engelmann spruce, and whitebark pine are found at higher elevations. The Gros Ventre River is a major migration corridor between the Jackson Hole area and Upper Green River for antelope and, to some extent, for elk that summer in the area. There are small populations of genetically pure Yellowstone cutthroat trout in some tributaries of the Gros Ventre River. Grizzly bear and wolf activity is increasing in this area, and it is a major linkage for the north-south movement of these animals expanding southward beyond the Hoback River or crossing the Upper Green to the Wind River Range.

Targets List:

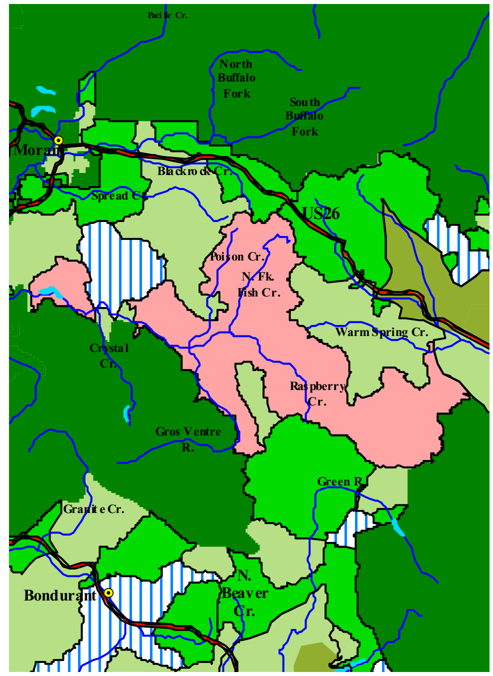


Animals:
Bald eagle
Columbia spotted frog
Great gray owl
Northern leopard frog
Yellowstone cutthroat trout

Plants:
Boreal draba
Compact gilia
Narrowleaf goldenweed
Railhead milkvetch
Single-head pussytoes
Teton golden-aster
Teton wire-lettuce

Plant communities:
Booth willow/mesic graminoid

Idaho willow/mesic forbs
Idaho willow/tufted hairgrass
Salix eastwoodiae / *Carex aquatilis* shrubland



GAP vegetation:
Alpine Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Limber Pine
Doug Fir/Lodgepole Pine
Lodgepole
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Sagebrush
Alpine Herbaceous
Burn_herbaceous
Dry Meadow
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

<u>Ownership</u>: 0.8% private, 99.2% public

<u>Possible Threats and Management Issues</u>

- Improper Grazing Practices
- Residential Development
- Energy Development (in the Bridger-Teton National Forest)

Buffalo Bill Reservoir on Shoshone River with Absaroka Mountains beyond. (C) George Wuerthner

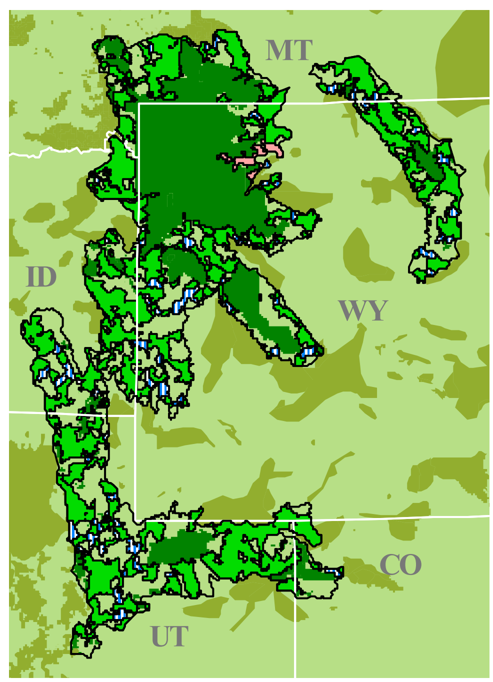
<u>Site Name</u>: Upper Shoshone
<u>Size</u>: 170,388 acres
<u>Quadrant</u>: 1
<u>Irreplaceability Score</u>: 80.5
<u>Vulnerability Score</u>: 83.6
<u>Combined Score</u>: 164.1

<u>Site Description</u>: The Upper Shoshone site lies along the eastern slope of the Absaroka Mountains west of Cody, Wyoming. It includes both the South Fork and North Fork Shoshone River drainages. On the south, it borders a site in TNC's Wyoming Basins portfolio. Watersheds include Bobcat Creek, Houlihan Creek, and Hardpan Creek on the South Fork drainage, plus Whit Creek, Elk Fork, Sweetwater Creek, Trout Creek, Rattlesnake Creek, and Trail Creek. This site is largely surrounded by wilderness, including the Washakie Wilderness and the North Absaroka Wilderness. The Absaroka Mountains are volcanic in origin and highly erodible. Streams carry heavy sediment loads after summer flash floods due to thunderstorms. The area lies in the rain shadow of the mountains, so is a major big game wintering area with large herds of elk, mule deer, and some of the largest big horn sheep herds in the ecoregion. Grizzly bear and wolf numbers are increasing, while wolverine are reported for the higher mountain areas. A number of rare plants are found on the limestone outcrops on Rattlesnake Mountain and elsewhere. This site has the highest combined irreplaceability plus vulnerability score of all megasites in this portfolio.

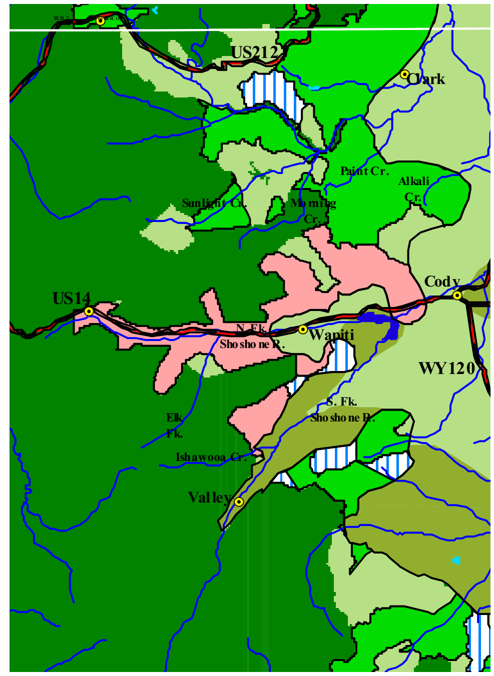
<u>Targets List</u>:

Animals:
Columbia spotted frog
Rufous hummingbird
Yellowstone cutthroat trout

Plants:
Absaroka beardtongue
Absaroka biscuitroot
Absaroka goldenweed
Alpine poppy
Cocks-comb paintbrush
Halls fescue
Howard forget-me-not
Kirkpatricks ipomopsis
Moschatel
North Fork Easter daisy
Seaside sedge
Shoshonea
Siberian kobresia



Snow paintbrush
Stoloniferous pussytoes
White arctic whitlow-grass
Wyoming tansymustard



Plant communities:
Ross avens-trifolium spp.?

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Juniper Western
Lodgepole
Pinyon-Juniper
Spruce
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 10.7% private, 89.3% public

<u>Possible Threats and Management Issues</u>

- Improper Grazing Practices
- Dispersal of Weed Seeds
- Irrigation Practices
- Residential Development (fragmentation)
- Conversion to Agriculture or Silviculture
- Energy Development
- High Use Roadways (wildlife movement affected)

Eastern slope of Big Horn Mountains.
(C) George Wuerthner

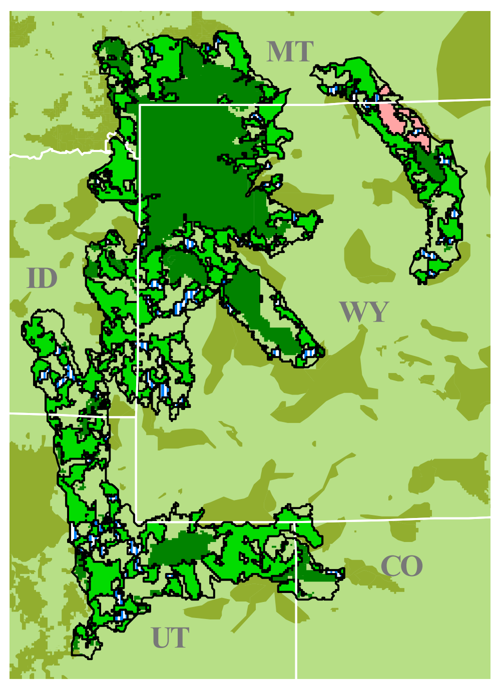
Site Name: Upper Tongue
Size: 332,385 acres
Quadrant: 2
Irreplaceability Score: 69.8
Vulnerability Score: 31.3
Combined Score: 101.1

Site Description: The Upper Tongue site takes in the northeastern portion of the Bighorn Mountains. It borders a TNC Wyoming Basins site. Drainages in the site include Big Goose Creek, Upper Tongue River including Wolf Creek and Columbus Creek, East and West Pass Creek, and Upper Little Bighorn Creek, all in Wyoming, plus the upper watershed of Rotten Grass Creek in Montana. The Bighorn Mountains contain a granitic core overlain with sedimentary rocks, in particular, limestone. The higher elevations consist of extensive meadows fringed by aspen. At the lowest elevations are ponderosa pine. Genetically pure Yellowstone cutthroat trout are reported for a few drainages in the Upper Tongue River. There are large elk and mule deer herds in these mountains, with important winter areas on the eastern flank. Moose, not native to the range, are expanding in this area. As a boreal island of habitat, populations of species such as marten, snowshoe hare, and water vole may be genetically unique. The eastern slope of the Big Horns receive greater precipitation than the western slope, with deeper snow in winter creating problems for wintering wildlife.

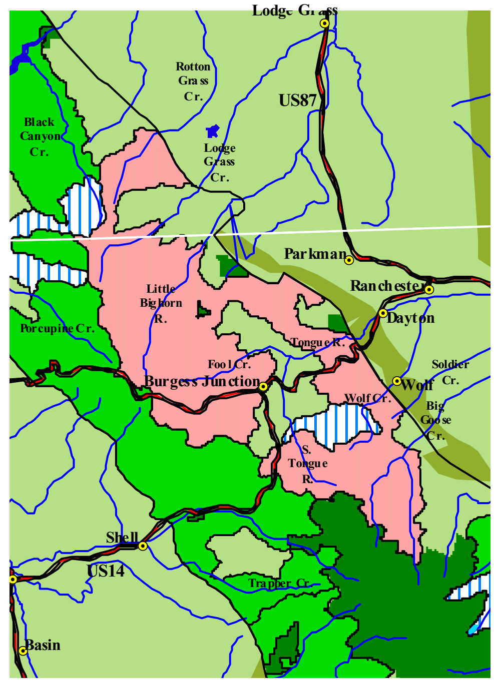
Targets List:

Animals:
Columbia spotted frog
Northern goshawk
Northern leopard frog
Rubber boa
Water vole
Wood frog
Yellowstone cutthroat trout

Plants:
Bighorn fleabane
Fragile rockbrake
Green spleenwort
Hapemans sullivantia
Howard forget-me-not
Northern arnica
Pink agoseris
Sheathed musineon
Soft aster



Woodland horsetail
Woolly twinpod



Plant communities:
Engelmanns spruce/redosier dogwood
Pinus flexilis / *Festuca idahoensis* woodland
Pinus flexilis / *Juniperus communis* woodland
Water birch/redosier dogwood

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Spruce
Aspen/Conifer
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

Ownership: 6.1% private, 93.9% public

Possible Threats and Management Issues

- Improper Grazing Practices (impacts riparian habitat)
- Diversions of Water (affects fisheries)
- Residential Development (impacts wildlife movement)

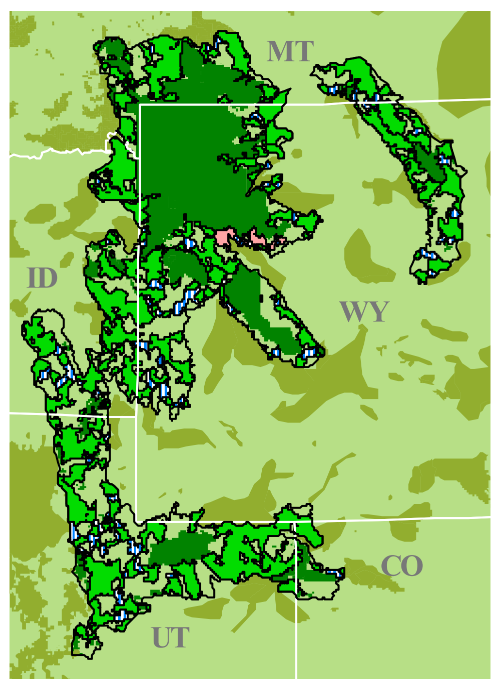

Upper Wind River. (C) George Wuerthner

Site Name: Upper Wind
Size: 167,651 acres
Quadrant: 1
Irreplaceability Score: 87.7
Vulnerability Score: 61.2
Combined Score: 148.9

Site Description: The Upper Wind site borders a site in TNC's Wyoming Basins portfolio. The Wind River Range lies to the south and west, while the Absaroka Range makes up the northern and eastern borders. The site is adjacent to the Waskakie Wilderness in the Absaroka Mountains on the north. The Dunoir Creek roadless area and other areas that fringe the existing wildernesses are all proposed by environmentalists for additional wilderness protection. The East Fork and Spence Morety Wildlife Management Areas lie in the site. Drainages in the site include South Fork Owl on the east, plus Pine Creek, Alkaki Creek, East Fork Wind River, Bear Creek Wiggens Fork, Burroughs Creek, Dunoir Creek, Middle Fork Long Creek, West Fork Long Creek, and Brooks Lake Creek. The Upper Wind area receives scant precipitation, and what precipitation that does occur as snow is frequently blown away. As a result the area provides exceptional winter habitat for large ungulates. The Upper Wind is a major elk wintering area with more than 7,000 animals. It is the only elk herd in northwest Wyoming that does not rely upon feedgrounds. The Whiskey Mountain bighorn sheep herd numbers almost a thousand animals and is the largest in Wyoming. The area also supports grizzly bears, wolves, and an occasional lynx.

Targets List:

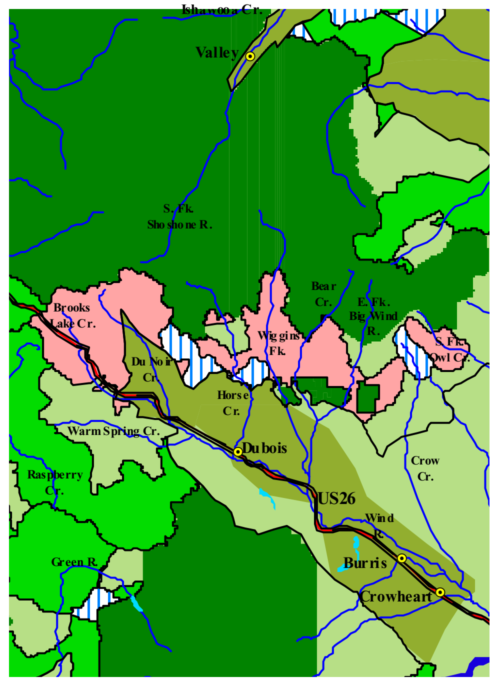
Animals:
Boreal owl
Columbia spotted frog
Northern leopard frog
Western boreal toad
White-winged crossbill
Yellowstone cutthroat trout



Plants:
Aromatic pussytoes
Narrowleaf goldenweed
Paysons draba
Pink agoseris
Rocky Mountain twinpod
Taprooted fleabane
Twinleaf cinquefoil
Wyoming tansymustard

Plant communities:

Booth willow/mesic forb
Booth willow/mesic graminoid
Geyers willow/mesic forbs
Idaho willow/tufted hairgrass
Pinus albicaulis / *Juniperus communis* woodland
Pinus albicaulis / *Vaccinium scoparium* forest
Salix eastwoodiae / *Carex aquatilis* shrubland



GAP vegetation:
Alpine Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Alpine Fir/Whitebark
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Pinyon-Juniper
Spruce
Whitebark/Limber Pine
Aspen
Montane Shrub
Mountain Sage
Sagebrush
Alpine Herbaceous
Burn_herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian

<u>Ownership</u>: 17.6% private, 82.4% public

<u>Possible Threats and Management Issues</u>

- Improper Grazing Practices
- Predator Conflict Practices (particularly wolves)
- Irrigation Practices (dewatering of Wind River & tributaries)
- Conversion to Agriculture or Silviculture
- Residential Development
- Energy Development
- Expansive Road Network

Upper Yellowstone River with Gallatin Range beyond. (C) George Wuerthner

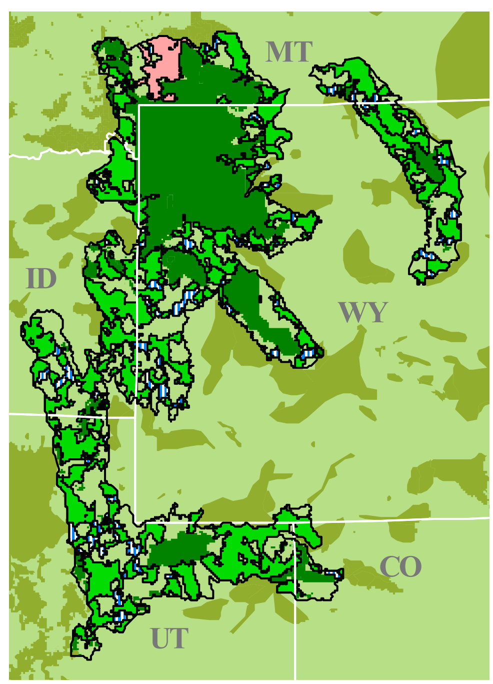
Site Name: Upper Yellowstone-Upper East Gallatin
Size: 486,501 acres
Quadrant: 3
Irreplaceability Score: 13.6
Vulnerability Score: 83.6
Combined Score: 97.2

Site Description: The Upper Yellowstone-Upper East Gallatin site is a very large site that takes in the entire upper Yellowstone drainage from Yellowstone National Park north to Livingston, Montana. It is adjacent to the Absaroka Beartooth Wilderness on the east. The Gallatin Range takes in the western side of the site and is the largest unprotected roadless area in the Montana portion of the ecoregion. This site borders a TNC Northern Plains portfolio site. Watersheds in the very upper East Gallatin River drainage include Bear Creek and Middle Creek. Vegetation includes limited amounts of juniper at lower elevation, mixed with grasslands and sagebrush. Higher up are Douglas-fir, aspen, lodgepole pine, Engelmann spruce, subalpine fir, and whitebark pine. Extensive meadows are found in both the Gallatin and Absaroka Ranges. The upper Yellowstone lies in the rainshadow of the mountains and is a major wintering area for antelope, elk, bighorn sheep, mule deer, and bison that wander out of Yellowstone NP. The Gallatin Range is one of the best areas for grizzly bears in the entire ecoregion, and there is increasing wolf presence. Several streams in the area harbor genetically pure populations of Yellowstone cutthroat trout, including Mol Heron Creek and Mill Creek. In winter the area supports a high number of bald eagles that feed upon carcasses of dead ungulates. The Yellowstone River is the longest undammed river left in the lower 48 states, and its natural flow regime supports one of the more intact cottonwood forests in the ecoregion.

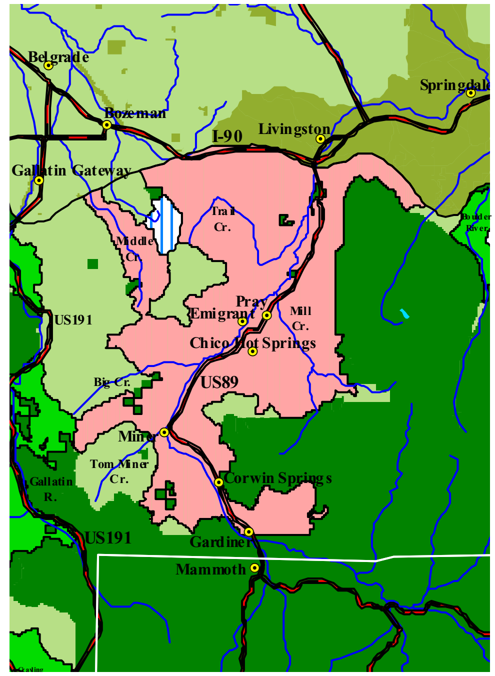
Targets List:

Animals:
Bald eagle
Berrys mountainsnail
Boreal owl

Plants:
Annual Indian paintbrush
Austins knotweed
Beaked spikerush
Beautiful fleabane
Many-ribbed sedge
Oregon checker-mallow
Rocky Mountain dandelion



GAP vegetation:
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Western
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Whitebark/Limber Pine
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Sagebrush Steppe
Salt Desert Scrub
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland



<u>Ownership</u>: 51.6% private, 49.4% public

<u>Possible Threats and Management Issues</u>

- Rip-rapping in Upper Yellowstone River (affects natural stream flow & regeneration of cottonwoods along the banks)
- Recreational Infrastructure Development
- Road Network Development (due to logging)
- Sedimentation of Streams (due to logging)
- Residential Development
- Improper Logging Practices (in Mill Creek and other drainages)
- Predator Conflict
- Management of/for Bison (Takings)
- Irrigation Practices

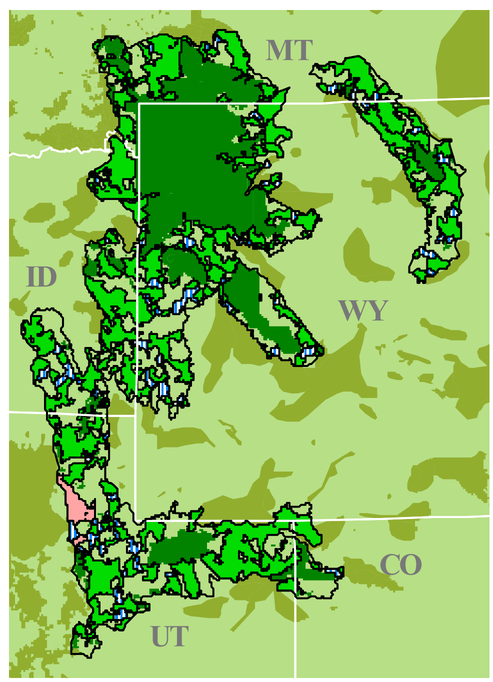
Housing tracts near Bountiful. Wasatch Front. (C) George Wuerthner

<u>Site Name</u>: Wasatch Front
<u>Size</u>: 255,344 acres
<u>Quadrant</u>: 3
<u>Irreplaceability Score</u>: 38.2
<u>Vulnerability Score</u>: 98.5
<u>Combined Score</u>: 136.7

<u>Site Description</u>: The Wasatch Front site borders Utah's most populated valley. It includes most of the western slope and highest peaks in the Wasatch Range near Salt Lake City and northward, including Bountiful and other bedroom communities. Drainages in the area include Red Butte Creek, Emigration Creek, Weber River, Deep Creek, East Canyon Creek, and Dalton Creek, with Ogden River forming the northern boundary. Vegetation includes Gambel's oak and bigtooth maple at lower elevations, giving rise to aspen, white fir, and subalpine fir at higher elevations. The western flank of the Wasatch Range rises rapidly to high peaks, with a limited amount of winter range remaining along its lowest elevations, which in the past was used by mule deer, but is increasingly being utilized by elk. Moose, non-native to the range, are also expanding into this area. Mollusks are well represented in this site, with many already extirpated or threatened. Relict populations of Bonneville cutthroat trout are known from several drainages in this area. Red Butte Creek has never been grazed and represents a unique natural area just outside of Salt Lake City proper.

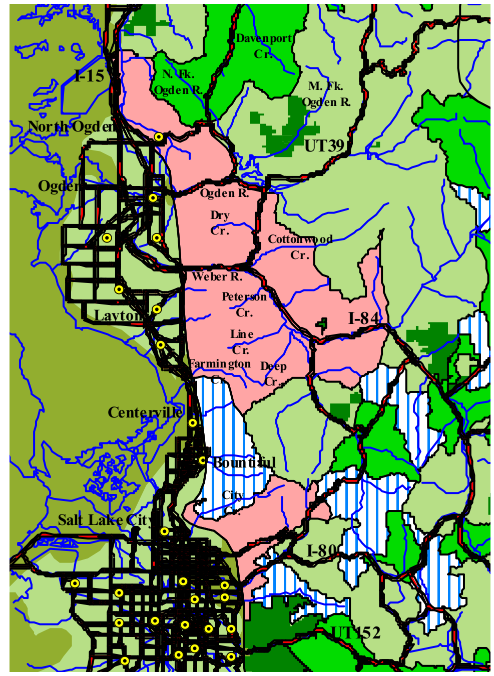
<u>Targets List</u>:

Animals:
Bald eagle
Bonneville cutthroat trout
Desert mountainsnail
Gambels crayfish
Green River pebblesnail
June sucker
Least chub
Lyrate mountainsnail
Northern river otter
Sharp-tailed grouse
Toquerville springsnail



Plants:
Broadleaf penstemon
Draba sp 2 (d. Burkei nom. Nov.)
Hooded ladies-tresses
Small yellow ladys-slipper
Utah fleabane

Utah ivesia
Wasatch rockcress



GAP vegetation:
Alpine Fir/Spruce
Doug Fir or White Fir
Juniper Utah
Pinyon
Pinyon-Juniper
Aspen
Aspen/Conifer
Maple
Mountain Mahogany
Oak
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Salt Desert Scrub
Dry Meadow
Grassland
Barren
Lowland Riparian
Mt. Riparian

<u>Ownership</u>: 66.5% private, 33.5% public

<u>Possible Threats and Management Issues</u>

- ■ Residential Development (population boom)
- ■ Recreational Infrastructure Development
- ■ Diversion of Water for Agriculture and Human Consumption
- * Rated highest in vulnerability (along with South Wasatch) of all the megasites

Weber River. (C) George Wuerthner

Site Name: Weber- Lost Creek
Size: 202,483 acres
Quadrant: 3
Irreplaceability Score: 7.5
Vulnerability Score: 83.6
Combined Score: 91.1

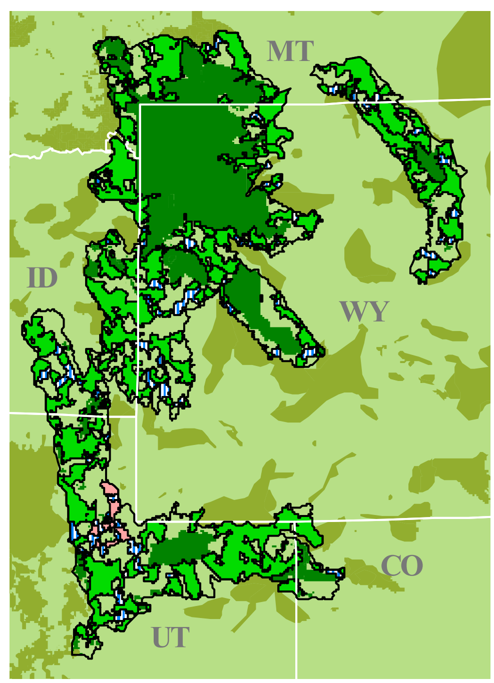
Site Description: The Weber-Lost Creek site is named for the two major watersheds that lie beyond the main divide of the Wasatch Front. The site includes Silver Creek in its southwest part and Chalk Fork Creek in the southeast, plus Grass Creek, Echo Canyon, and Lost Creek. After crossing the steep western flank of the Wasatch Range, the uplands open up to more rolling, gentle terrain covered with Gambel's oak, bigtooth maple, aspen, and white fir. The area supports mule deer and growing herds of moose and elk. A number of streams in this area support native Bonneville cutthroat trout, plus some rare mollusks. The area has some potential of supporting wolves if they recolonize northwest Utah.

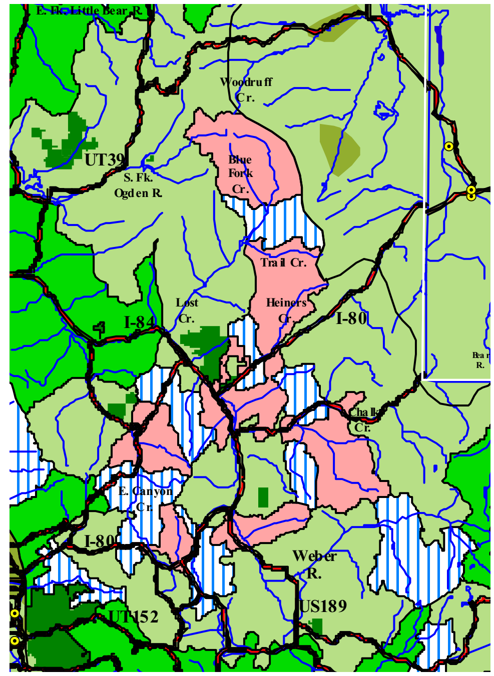
Targets List:

Animals:
Bald eagle
Bonneville cutthroat trout
Deseret mountainsnail
Gambels crayfish
Green River pebblesnail
Northern river otter
Osprey
Sandhill crane
Toquerville springsnail
Western toad

Plants:
Echo spring-parsley
Hall milkweed
Logan wild buckwheat

GAP vegetation:
Alpine Fir/Spruce
Doug Fir or White Fir
Juniper Utah
Lodgepole
Pinyon





Pinyon-Juniper
Aspen
Aspen/Conifer
Mountain Mahogany
Oak
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Dry Meadow
Grassland
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian

Ownership: 94,5% private, 5.5% public

Possible Threats and Management Issues

- Major Transportation Corridor (barrier to wildlife movement)
- Improper Grazing Practices
- Residential Development
- Diversion of Water for Livestock and Domestic Use
- Predator Conflict Practices (with the reestablishment of wolves)

Limestone cliffs in Ten Sleeps Canyon. (C) George Wuerthner

Site Name: West Bighorn
Size: 182,284 acres
Quadrant: 2
Irreplaceability Score: 80.1
Vulnerability Score: 23.9
Combined Score: 104.0

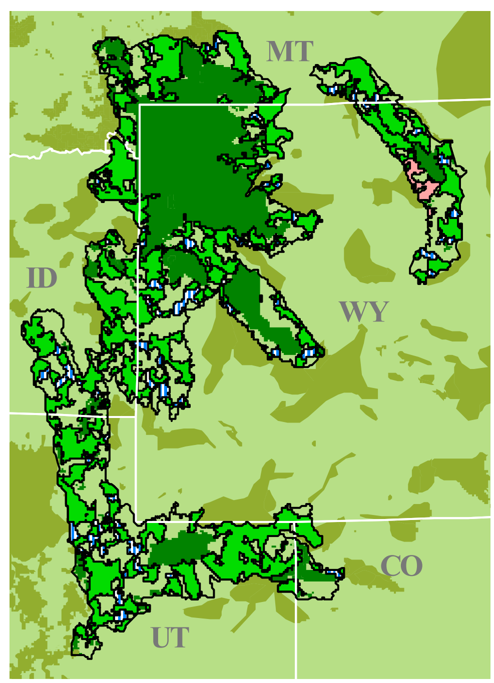
Site Description: The West Bighorn sites takes in the western slope of the Bighorn Mountains. It borders a TNC Wyoming Basin's portfolio site and the TNC Ten Sleeps Preserve. Drainages in the site include Spring Creek, Ten Sleeps Creek, Broken Rack Creek, and Paint Rock Creek (the most northerly). The Bighorn Mountains rise dramatically from the arid lowlands to 13,000-foot granite peaks. The flanks of the range consist of outcrops of limestone and other sedimentary rock, and provide a feeling of being in southern Utah canyon country rather than in the Rockies. Juniper is intermixed with grasses on the lower slopes, with aspen and beautiful flowery parks found at higher elevations. This is the only place on the western slope of the Bighorns with stands of ponderosa pine. While the flanks of the range are steep, the upper elevations tend to be rolling. Elk and mule deer are abundant on the western slope, with BLM land providing some publicly owned winter range at lower elevations. In this boreal isolate habitat, marten, snowshoe hare, and water shrew, among other species, may be genetically distinct.

Targets List:

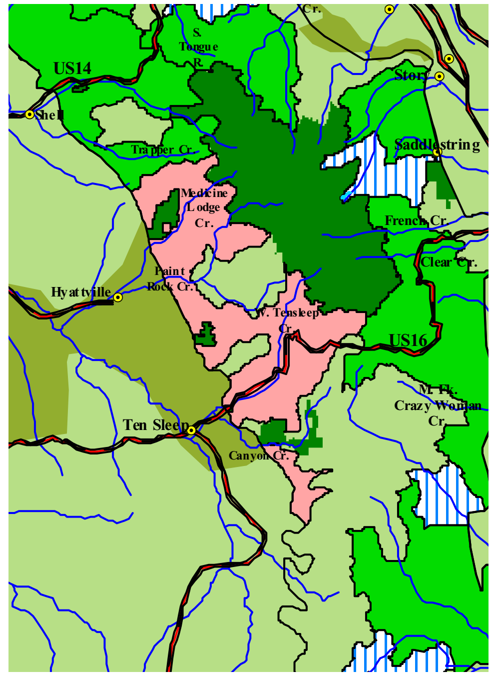
Animals:
Northern goshawk

Plants:
Bighorn fleabane
Cary beardtongue
Coil-beaked lousewort
Green spleenwort
Hapemans sullivantia
Moschatel
Mountain lousewort
Northern arnica
Pink agoseris
Soft aster
Watsons prickly-phlox
Zephyr windflower

Plant communities:
Bristly black gooseberry/tall fringe bluebells



Pinus flexilis / *Juniperus communis* woodland
Salix planifolia / *Deschampsia cespitosa* shrubland



GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Juniper Utah
Lodgepole
Pinyon-Juniper
Ponderosa Pine
Spruce
Aspen/Conifer
Greasewood
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 19.8% private, 80.2% public

<u>Possible Threats and Management Issues</u>

- Repeated Recreational Vehicle Use
- Dispersal of Weed Seed
- Improper_Grazing Practices
- Irrigation Practices
- Recreational Roadway Network

West slope of Tetons from Pierre's Hole.

Site Name: West Slope Teton
Size: 148,776 acres
Quadrant: 1
Irreplaceability Score: 50.3
Vulnerability Score: 68.7
Combined Score: 119.0

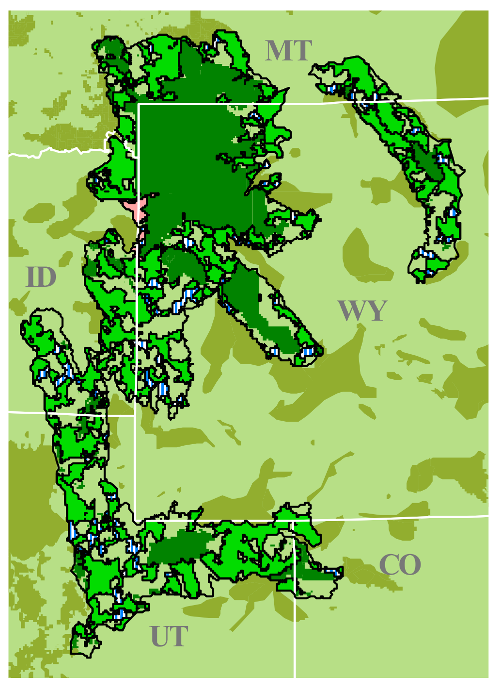
Site Description: The West Slope Teton site includes the western slope of the Teton Range as well as Pierre's Hole in the upper Teton River basin. It is immediately adjacent to a TNC Columbia Basin portfolio site. Starting in the south, the watersheds in this site include Trail Creek, Spring Creek, Teton Creek, South Fork Badger Creek, Bitch Creek, Conant Creek, and Squirrel Creek. The valley floor once had extensive wetlands, and even today there are an estimated 15,000 acres of wetlands. The mountains are densely covered with aspen, and pockets of aspen extend out into the agricultural lands. Much of the valley floor has been converted to crops (potatoes) as well as pasture and hay production, destroying native plant communities. There are reports of wolverine in the Tetons as well as the potential for grizzly and wolf recolonization. Harlequin ducks are reported to nest in a few streams on the western flanks.

Targets List:

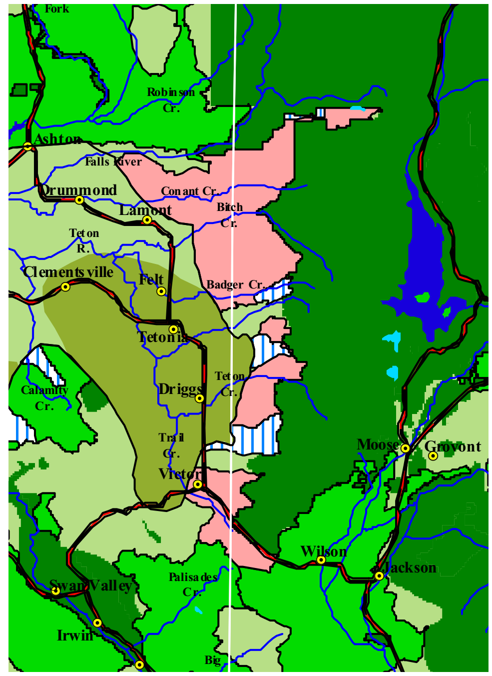
Animals:
Boreal owl
Bufflehead
Common loon
Flammulated owl
Great gray owl
Harlequin duck
Lynx
Northern goshawk
Peregrine falcon
Trumpeter swan

Plants:
Bulb-bearing water-hemlock
Green spleenwort
Paysons bladderpod

Plant communities:
Bladder sedge
Booth willow/bladder sedge
Booth willow/Kentucky bluegrass
Engelmann spruce/common horsetail



Engelmann spruce/red-osier dogwood
Geyer willow/mesic forb



GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Spruce
Aspen
Aspen/Conifer
Montane Shrub
Mountain Sage
Sagebrush Steppe
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland

<u>Ownership:</u> 17.8% private, 82.2% public

<u>Possible Threats and Management Issues</u>

- Conversion to Agriculture or Silviculture (>1000 acres in crops)
- Improper Grazing Practices
- Residential Development
- Recreational Infrastructure Development
- Predator Conflict
- Conversion of Wetlands to Agriculture

Hebgen Lake from Horse Butte. (C) George Wuerthner

<u>Site Name:</u> West Yellowstone
<u>Size</u>: 108,986 acres
<u>Quadrant</u>: 3
<u>Irreplaceability Score:</u> 48.0
<u>Vulnerability Score:</u> 68.7
<u>Combined Score</u>: 116.7

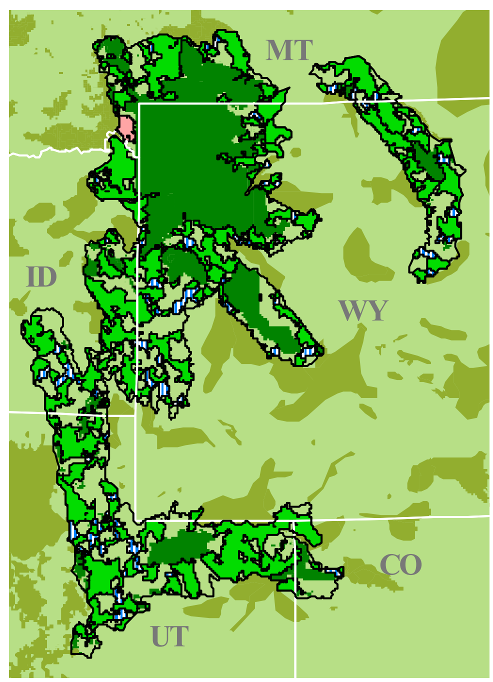
<u>Site Description</u>: The West Yellowstone site lies just west of Yellowstone National Park. It includes the upper Madison River, including the tributaries Beaver Creek, South Fork of the Madison, Watkins Creek, and Red Canyon Creek in the southern end of the Madison Range. Grayling Creek, which has its headwaters in the park, is also part of the site. It borders a TNC Middle Rockies portfolio site that includes the Madison River Valley and Centennial Valley. The Lionhead roadless area is a proposed wilderness. Extensive meadows combined with dense lodgepole pine forests is the dominate vegetation. The area is heavily used by grizzly bear and an occasional wolf. Moose, elk, and even a few antelope use the area in summer, though most move to lower elevations in winter. Bison moving out of Yellowstone Park utilize the area until they are shot by the Montana Livestock Department as part of their anti-bison program (i.e., bison are not allowed to enter Montana—the only native species specifically excluded from entering the state). Westslope cutthroat trout persist in a few small tributaries to the Madison River. A few bald eagle nest in the area, along with osprey. As the first part of a linkage westward towards the Centennial and Gravelly Ranges, this area has high importance as a migratory and movement corridor.

<u>Targets List:</u>

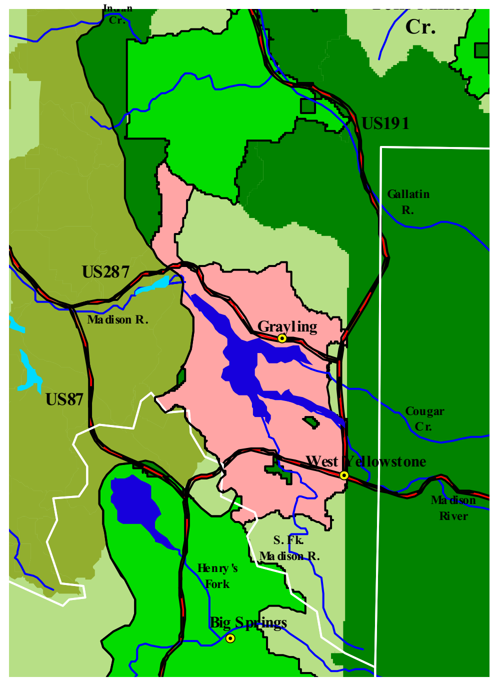
Animals:
Bald eagle
Peregrine falcon

Plants:
Joves buttercup
Slender Indian paintbrush
Slender thelypody
Wolfs willow

GAP vegetation:
Alpine Fir
Alpine Fir/Doug Fir
Alpine Fir/Lodgepole
Alpine Fir/Spruce
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole



Pinyon-Juniper
Whitebark/Limber Pine
Aspen
Aspen/Conifer
Burn_Shrub
Montane Shrub
Mountain Sage
Sagebrush Steppe
Alpine Herbaceous
Burn_herbaceous
Dry Meadow
Grassland
Perennial Grass Montane
Tall Forb Montane
Wet Meadow
Barren
Lowland Riparian
Mt. Riparian
Wetland



<u>Ownership:</u> 10.1% private, 89.9% public

<u>Possible Threats and Management Issues</u>

- Management of/for Bison (Takings)
- Residential Development
- Operation of Dam (along Madison River)
- Logging Road Network

Moonrise over Absaroka Mts and elk. (C) George Wuerthner

Site Name: Wood River
Size: 59,149 acres
Quadrant: 2
Irreplaceability Score: 75.5
Vulnerability Score: 38.8
Combined Score: 114.3

Site Description: The Wood River site lies on the eastern slope of the volcanic Absaroka Range. The Wood River is a major tributary of the Greybull River. It borders a site in TNC's Wyoming Basins portfolio. The Washakie Wilderness lies on the western border. The area supports elk, mule deer, and bighorn sheep herds. Increasing use by grizzlies and wolves is occurring. The area contains some of the least visited parts of the Greater Yellowstone Ecosystem and has a number of rare plants.

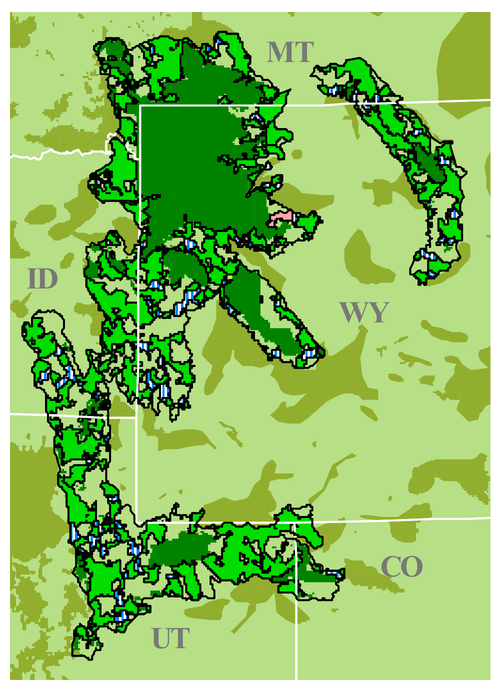
Targets List:

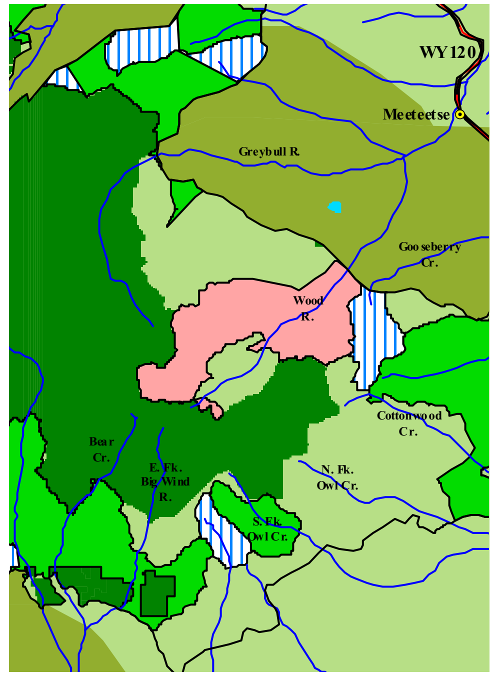
Animals:
Yellowstone cutthroat trout

Plants:
Alpine poppy
Kings campion
Kirkpatricks ipomopsis
Mountain lousewort
Northern white rush
Rockcress draba
Seaside sedge
Twinleaf cinquefoil
Wyoming tansymustard

Plant communities:
Booth willow/mesic graminoid

GAP vegetation:
Alpine Fir
Doug Fir
Doug Fir/Lodgepole Pine
Lodgepole
Pinyon-Juniper
Spruce
Whitebark/Limber Pine
Aspen





Aspen/Conifer
Burn Shrub
Montane Shrub
Mountain Sage
Sagebrush
Sagebrush Steppe
Alpine Herbaceous
Grassland
Wet Meadow
Barren
Mt. Riparian
Wetland

<u>Ownership</u>: 13.5% private, 86.5% public

<u>Possible Threats and Management Issues</u>

- Residential Development
- Improper Grazing Practices
- Irrigation Practices
- Predator Conflict
- Energy Development (specifically oil & gas drilling)