Searching for the best science available: a method for identifying a corridor-open space system for land use planning

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Abstract

Recognizing the potential for identifying, and possibly preserving large reserves of wildlife habitats, the Washington Department of Fish & Wildlife (WDFW) took the initiative to develop an open space plan for Spokane County's Comprehensive Plan. The goal of this open space plan was to identify, in a minimal amount of time, enough land to maintain the current native biodiversity of Spokane County.

After searching for potential sources of county-wide data, the Washington GAP data set was selected since it provided readily available geographical information in the form of large-scale vegetation maps and associated wildlife distribution maps for the entire county. The unknown variable in using GAP for this project was that it had been used only at statewide or larger regional scales, but never at a small local county scale.

The project was completed in 3 main phases. Data sets in these 3 phases were manipulated using a PC-based GIS system. The first phase was the initial identification of open space. Using the GAP data, species richness and species representation were combined to produce a draft open space plan comprising > 48% of Spokane County. For small projects like this one, overestimates may be expected when using GAP data that has a minimum resolution of 100 ha for upland sites and 40 ha for wetlands.

To address this shortcoming, a second phase was conducted to refine the proposed open space. Part of the refinement was a landscape analysis of the surrounding 5 counties to ensure that the reserves and corridors identified in Spokane were connected to reserves and corridors in the adjoining counties. In addition, county-specific, fine-scale GIS data were used to ensure that designated open space boundaries followed realistic topography and to help eliminate lands with high road densities and small parcel sizes. Wetland, river, and stream data were used for the localized delineation of open space. This refinement resulted in an open space system covering 30% of Spokane, a reduction of 18% from the first proposal.

A validation phase was the final step in this process. Seven field-derived data sets were compared to the proposed open space. Results were mixed. Omission error rates were <3% when compared to critical elk habitat, heron rookery locations, WDFW priority habitat and species locations, and public input. Yet, for sensitive plants, Heritage data, and herpetological data, omission errors were 30%, 31% and 33%, respectively. However, upon inspection of these errors, it was discovered that with an additional 2% of land added to the open space plan, error rates for these 3 data sets were reduced to <7%, and to <1% for the 4 other data sets.

In conclusion, when implementing local small-scale projects, GAP cannot be expected to produce the detailed, fine grain results necessary for delineating open space. GAP can however, be used as a starting point, subject to refinement, field evaluation, and correction.

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INTRODUCTION

Many urban areas have little ecological information available since most researchers and field biologists often leave the city to do their fieldwork. Armed with little data and not enough time or money to perform community or population viability studies, what method can be used to develop a reasonable and biologically defensible open space plan in only 2-3 months?

We recently faced this challenge in Spokane County, Washington. Like most other states, Washington is facing one of the greatest threats ever to its native wildlife. It is losing more than 30,000 acres of wildlife habitat each year. The Washington Department of Natural Resources (DNR) (1978) predicted that a city the size of Spokane will be added to Washington every 1.6 years. More than 2.2 million acres of forest habitat have been lost in the last 20 years. More than two-thirds of our old growth forests have been lost in the last 50 years, and more than 70% of the state's native grasslands have been lost due to vast land conversions (WA. DNR 1978). Recently, the U.S. Environmental Protection Agency's (EPA) Science Advisory Board identified habitat modification and loss of species diversity at the highest level of environmental risk to the country (U.S. EPA 1990). Obviously, habitat protection and management must be one of the central elements of all conservation strategies. With habitat destruction being the greatest threat to biodiversity, the protection of natural habitats should be the most effective way to conserve biodiversity.

Recognizing the potential for identifying, and possibly preserving large networks of wildlife habitats, the Washington Department of Fish & Wildlife (WDFW) took the initiative to develop an open space plan for Spokane County's Comprehensive Plan. WDFW searched for a method to identify a reasonable and publicly acceptable amount of critical county land in a minimal amount of time. The goal of this open space plan was to identify enough land to maintain the current native biodiversity of Spokane County. Once open space areas are identified, all efforts to conserve land by private individuals, state or federal agencies, counties and nonprofit land trusts can be focused on these lands, potentially preserving this critical network of wildlife areas. Having an open space plan also helps county planners and commissioners to direct development away from these lands and toward those areas outside the designated open space. Once identified, land speculators are able to avoid these critical lands, saving them both time and money by reducing environmental confrontations and legal challenges.

METHODS

Area

Spokane is located in eastern Washington near the boundary of Idaho. The City of Spokane is the second largest in Washington State with approximately 190,000 people living in the incorporated portion and another 199,000 living in the unincorporated portion of Spokane County (WA. Office Financial Management 1998).

The county is divided by 2 ecoregions: the Columbia Basin and the Northeast Corner. Within these 2 ecoregions, 5 major and 2 minor vegetation zones are found in the county (Table 1).

Spokane County is dominated by the Ponderosa Pine, and Palouse vegetation zones. The majority of the human population of the county is located within the Ponderosa Pine zone, which covers nearly half of the county. The Palouse grassland zone is located in the southeastern portion of the county and corresponds to the distribution of agriculturally significant loess soils that has been almost completely converted to wheat production (Cassidy 1997). The Interior Douglas Fir, Grand Fir, Interior Red Cedar, and Subalpine Fir zones are all located in the mountainous, northeastern portion of Spokane County. The Three-Tip Sage zone is located in the extreme western and southwestern portions of the county.

Associated with this diversity of vegetation is a diversity of wildlife. There are currently 244 vertebrate species predicted by GAP to occur in Spokane County (Dvornich et al. 1997, Johnson and Cassidy 1997, Smith et al. 1997). Washington GAP (WAGAP) currently only predicts the distribution of 3 main vertebrate groups: mammals, birds, and herps (reptiles and amphibians). The number of species for each taxa predicted for Spokane County are 66 mammals (59% of state total), 161 birds (71%), and 17 reptiles and amphibians (35%).

Data Source

With little biological data on hand, it was necessary to use all comprehensive geographic information available for the native species and communities of Spokane County. After searching for potential sources of such countywide data, the Washington GAP data set was selected since it provided readily available geographical information in the form of large-scale vegetation maps and associated wildlife distribution maps for the entire county.

GAP uses satellite imagery with a geographical information system (GIS) to create current vegetation maps from which the distribution of amphibians, reptiles, birds and mammals can then be derived along with a map of land ownership. Areas important to individual species, groups of species or areas of high biological diversity (species richness) can then be identified and analyzed. This study needed vertebrate species range and distribution information, as well as current public landholding for identifying potential open spaces. GAP provided all of these tools. The main concern in using GAP for this project was that it had been used only at statewide and regional scales, never at a local county scale.

The GAP land cover for Washington State is based on 1991 Landsat Thematic Mapping (TM) imagery. Polygons were created manually by outlining areas of uniform cover type using Arc/Info GIS software. Polygons were drawn with a 100 ha (247 acres) minimum mapping unit for terrestrial cover types and a 40 ha (99 acres) minimum mapping unit for wetlands (i.e. the area of each polygon was ^{3}100 or 40 ha (247 or 99 acres), respectively). For Spokane County, there were a total of 283 polygons. For this project, we analyzed the GAP data layers and database using Environmental Systems Research Institute's (ESRI) ARCVIEW on a PC and ARC/INFO on a UNIX workstation.

Initial Identification of Proposed Open space

Four layers derived from the GAP database were used to produce a draft open space plan. For each data set a GIS layer, or map, was generated. These layers were then manipulated using a variety of methods to arrive at the results. The University of Washington's Department of Urban Design and Planning completed this phase of the project in cooperation with the Washington Department of Fish & Wildlife (Univ. of Washington 1998).

Species Richness

This layer was created by including all polygons having the highest number of species for each taxa in Spokane County. Since species richness is relative to the total number of vertebrates (by group) within the study area, only polygons having ^{3}75% of all possible mammal and bird species and those with ^{3}50% of all possible reptiles and amphibians (herps) were selected. A lower threshold inclusion rule for herps was used because their populations, particularly amphibians, are distributed primarily between spatially concentrated and restricted habitats such as wetlands, rivers and lakes. A higher threshold inclusion rule for birds and mammals was used because of the wide distribution of these taxa across a variety of habitats. These species richness maps quickly convey which areas of the County are home to the greatest number of vertebrate species.

Representation

This layer contains the minimum number of polygons in which all predicted species for Spokane County can be represented. The purpose of representation is to ensure that every native species predicted to occur in the County is recognized at least once by a subset of all the County's WAGAP polygons. Representation guarantees that all species predicted to occur in the County are included within the product (Csuti et al. 1996, Pressey et al.1997). This approach is similar to the representative set solutions discussed by Pressey and others (Church et al. 1996; Csuti et al. 1996; Williams et al. 1996; Pressey et al. 1997; Stokland 1997).

Riparian Corridors and Lakes

Riparian corridors were selected as the backbone for our open space system because of their widespread presence in Spokane County and because of their disproportionately significant contribution to biodiversity (Naiman et al. 1993). Wherever current land use permitted, corridors were drawn at a minimum of 0.4 km (0.25 mi) to 0.8 km (0.5 mi) wide on center in order to protect riparian vegetation and provide adjacent movement corridors that are wide enough to avoid edge effects and human disturbance. Major lakes were mapped and buffered as well.

Connections Between Isolated Open spaces and Riparian Systems

Connections between isolated open spaces were made by identifying and selecting polygons with high species richness and natural land cover between the reserves. Consideration was given to line-of-sight connections, natural barriers such as cliffs and large rivers, continuity of land cover, width of connections, and level of internal and adjacent development. As additional considerations, long connections across dry landscapes were not made to connect areas important for amphibians, while numerous wide connections were made for mammals (Rosenberg et al. 1997).

Refinement of Draft Open Space

A landscape analysis of the WAGAP data was completed for the five counties surrounding Spokane County. The larger 6 county (5 counties plus Spokane) data set for vegetation, mammals, birds, and herps was used to ensure that identified reserves and corridors were connected to potential reserves and corridors in the 5 adjacent counties.

A USGS digital elevation model (DEM) was used to ensure that designated open space boundaries followed realistic gradients and topography. The draft map of vertebrate richness, representation and connections was overlaid on a 100-foot contour topographic map derived from the DEM layer. Boundaries were made to coincide with natural valleys, ridges, and realistic elevation gradients avoiding steep cliffs and drop offs.

A parcel layer and a primary roads layer were used as indicators for the location and intensity of both current and future human development and activity. Land with high road density and small parcel size was eliminated, whereas land with large roadless areas and large parcel size was incorporated. The road layer was used to eliminate areas that were bisected and fragmented by major roads or those with high road density (Ashley 1996; Reijnen 1997). Open space that had to cross a road was selected in areas with low development and low parcel size. Open space was not permitted to repeatedly cross a road. By overlaying the parcel layer on our proposed open space map, open space lands were routed through areas with parcel sizes >8 ha (20 acres).

Finally, wetland, river, and stream data were used for delineating corridors, especially those for amphibians and birds. Areas of the county, which had extremely high concentrations of wetlands (i.e. southwestern section of county), were included in the proposed open space. Extensive tracts of agricultural land were eliminated in the western part of the county leaving only riparian areas and their buffers.

Field Data Validation and Final Version

In order to test the proposed open space plan with all existing field data for Spokane County, 7 field-derived data sets were compared to the GAP open space results. The following paragraphs describe these field data sets.

WDFW Priority Habitat and Species (PHS) Data

The Washington Department of Fish and Wildlife (WDFW) established and maintains the Priority Habitat and Species (PHS) database. This database contains both habitats (polygons) and species that have been designated as critical or unique.

WDFW Heritage Points

This is WDFW's statewide point database for wildlife sightings. The majority of observations are authored by state biologists. This database was used to verify species rich areas as identified by GAP, and to ensure that state sensitive species were generally included in the proposed open space plan.

WDFW Herp Points

This is a separate database maintained by WDFW. It contains all point observations for reptiles and amphibians statewide. It was used to corroborate the GAP herp distribution.

DNR Sensitive Plant Species

This database, maintained by the Washington Department of Natural Resources (DNR), contains all point locations for sensitive plants statewide. This plant database was used as a test of biodiversity other than wildlife.

Great Blue Heron Rookery Locations

Great blue herons are a unique test due to their colonial nesting behavior. This test will indicate how well critical riparian or lentic habitats have been incorporated in the plan.

Elk Data

The elk data for Spokane County, generated by WDFW wildlife biologists, were collected and compiled by the Rocky Mountain Elk Foundation for their own GIS system. This data set will be used to determine if "critical" elk summer and winter range was included in the open space plan.

Public Input

Input on suggestions for open space was received from members of the Spokane County Audubon Society, the Spokane County WA Native Plant Society, from citizens participating in Spokane County's Public Meetings for Open Spaces, and from WDFW biologists. All data were combined into one data layer.

Omission error rates were calculated by comparing these field-validated data sets to our GIS based open space plan. The final open space plan was created by redrawing the open space boundaries to include most of these field points.

RESULTS

Using strictly GAP and GAP-derived data, an open space proposal with approximately 221,434 ha (546,942 acres) or 48% of Spokane County was identified by our process as being important for maintaining vertebrate biodiversity (Figure 1). This product was produced by combining areas of high species richness with areas of high species representation. Results for each separate layer were 48% for species richness and 32% for species representation.

With the use of non-GAP county-specific data, a refined open space plan was produced which identified approximately 30% (137,293 ha) of the county (Figure 2) as critical habitat, a substantial reduction from the initial 48%. It is important to note that the 30% of the county covered by the refined open space plan would result in an increase of 39% in protected habitat for Spokane County (Stevenson 1998).

A summary of the percent of data omitted by this refined open space plan when compared to the field-collected data sets is shown in Table 2.

When compared to the PHS data set, the refined open space plan's only omission, other than white-tailed deer, was moose (*Alces alces*) habitat located in the northeastern section of the county in and around Mt. Spokane State Park. The amount missed was less than 1%. Except for the ubiquitous white-tailed deer, all other PHS data were completely encompassed by the refined open space plan. Eighty-eight percent of all PHS critical white-tailed deer habitat was covered by the plan.

Twenty of the 64 WDFW Heritage points, roughly 31%, were omitted by the refined open space plan.

Species omitted by the refined plan included: prairie falcon (*Falco mexicanus*), osprey (*Pandion haliaetus*), grasshopper sparrow (*Ammodramus savannarum*) and Western bluebird (*Sialia mexicana*).

Sixty-one (33%) of the 183 WDFW Herp points were missed by the refined plan. Species missed by the plan were: Great-basin spadefoot (*Scaphiopus intermontanus*), Columbia spotted frog (*Rana luteiventris*), long-toed salamander (*Ambystoma macrodactylum*), and tiger salamander (*Ambystoma tigrinum*).

Fifty-two of the 173 DNR Sensitive Plants points were missed by the refined plan, roughly 30% of the total. Species omitted by the plan included: yellow lady's slipper (*Cypripedium parviflorum*), Howellia (*Howellia aquatilis*), Palouse goldenweed (*Haplopappus liatriformis*), and Spalding's silene (*Silene spaldingii*). All of the 8 known heron rookeries were included by the refined open space plan. Several critical elk (*Cervus elaphus*) habitat areas encompassing roughly 3% were omitted by the refined plan. All of the omitted areas were located in the eastern half of the county.

The public input data primarily reiterated the need to protect the current State Park lands and the riparian areas of Spokane and actually contributed little additional acreage to the refined plan. The total public input amounted to 47,740 ha or 10.4% of the county. The amount of land suggested by the public, but missed by the proposed plan, amounted to about 3.5% or 15,812 ha.

By redrawing the open space polygons to include most of our field-collected data points, it was found that an increase of only 2% of land mass in the open space plan, the omission error rates were reduced to below 8% for the herp, sensitive plant, and heritage data sets (Table 3). For the other data sets, this new coverage resulted in near complete inclusion of the field data.

DISCUSSION

Our goal was to come up with a biologically defensible open space plan for Spokane County while having little ecological data and no time or money to do any additional studies. Therefore, we relied upon GAP data – data that had only been used successfully on large-scale, statewide or region-wide studies. In this study, it was used on a small, countywide project. Consequently, the first data set derived solely from the large-scale GAP data resulted in an open space plan covering over 48% of Spokane County. At this point, it became apparent that GAP alone could not produce the fine-scale species distribution and range predictions needed for this project. Realistically, such detail cannot be expected when minimum base resolutions for WAGAP are 100 ha (247 ac.) for upland areas and 40 ha (99 ac.) for wetland areas. With polygons this size, it is similar to using a broad paintbrush to fill in "paint-by-numbers" polygons. Consequently, when using GAP data for small-scale projects, a "refinement" phase is necessary.

Both species richness and species representation were considered in this study since other studies have indicated that the combination of the 2 may be the best way to capture biodiversity (Pressey et al. 1994; Williams and Lathbury 1996; Stokland 1997). The identification of "species-rich areas" was described in Scott et al. (1993) and became widely associated with GAP as a means of focusing on "species-rich hot spots." Recent studies have shown that the species-rich areas of major taxa do not often coincide (Prendergast et al.1993; Lawton et al. 1994). As a result, emphasis on species richness has been replaced or at least accompanied with species representation, which has the goal of identifying complementary sets of geographic units that represent all species, rather than "hot spots" that tend to leave out some species (Williams and Lathbury 1996). Each approach has inherent errors and when combined, appear to result in a high percentage of errors for small-scale projects. As a result, the combination of these 2 approaches, especially when using large-scale GAP data is likely to overestimate the area necessary to preserve biodiversity in a small-scale project like this one.

To define open space at a county level, detailed data sets such as localized plant and animal observations, current and local land use (e.g. agriculture), road densities, housing densities, and local topographic features were used to arrive at a small-scale data set. This detailed data set is necessary to allow localized, county decisions to be made. It must be realized that this "refinement" phase is the most subjective of the entire process. To formalize this process, rules were established during this process (e.g. parcel sizes >8 ha, open space not permitted to repeatedly cross a road). However, the process is not automatic and ultimately a person has to make the final decision on where some of the open space boundaries will be drawn and just how wide to make them. Because of this subjectivity, and the potential increase for error, we felt it was not only important to identify and follow these rules, but also essential to corroborate our open space plan with field-validated data.

Using field data (Table 2) revealed that the refined open space plan did omit relatively large percentset, 30% of the sensitive plant data set, and 31% of the Heritage wildlife (non-herp) points. Yet, for three other data sets the proposed open space resulted in good coverage or inclusion, omitting <1% the PHS data, 0% of great-blue heron rookeries, 3% of elk data (3%), and 3.5% of the public input layer. The high omission error found with amphibians in this study is consistent with other studies. Herps were found to have the highest error rates of all 3 taxa in this study. However, the actual error rates we found appear to be higher than those reported by other studies. Edwards et al. (1996) reported mean error rates of 16% for amphibians, 10% for reptiles, and 5% for mammals. In Idaho, Scott et al. (1993) also reported amphibians as having the highest omission error rates of all taxa at 13.3%. For mammals, they reported an error rate of 11%. The higher error rates reported in our study can likely be attributed to its small scale (Table 2). These other studies were both large-scale projects, covering an entire state or region.

By redrawing the open space boundaries and including the field points that were initially omitted resulted in an increase of only 2% land mass, and of course, substantially reduced the omission error rates (Table 3). Some of this reduction in error may be expected with the increase in size. Edwards et al.(1996) noted that as the size of an area increases the likelihood of "capturing" more rare habitat types increases and the effects of habitat mapping errors are likely to diminish.

The project did reveal that GAP alone is not the perfect solution for small-scale projects. At the current resolution of the WAGAP data, it should be used as was intended - a readily available tool which can give a good prediction of vertebrate species distribution on a broad scale. The advantage of using GAP on a small-scale project like this one, is that it can quickly generate a complete set of species richness and species representation maps that can serve as substitutes for community and species specific data that is usually unavailable. However, it is important to recognize that when GAP data is used on small scale projects like this one, a refinement phase – one requiring biological expertise, and the use of more detailed smaller scale data sets – is required to arrive at a biologically defensible end product. Results also indicate that when decisions are made based on the results of GAP-generated data, users need to recognize that there seems to be a higher error rate for amphibians and reptiles than for the other vertebrate taxa (birds and mammals) and should amend or adjust their conservation plans or objectives accordingly.

The amount of land identified to be important for biodiversity may seem unreasonably large. However, as in our case, it should be noted that 32% of the county is far less land than some authors have suggested is necessary for the protection of biodiversity in any given region. For example, Metzgar and Bader (1992) determined that approximately 60% (32 million acres) of wild habitat is required to conserve biodiversity in the Northern Rockies. Ryti (1992) concluded that in order to represent all bird, mammal, reptile, and plant species on 18 islands in the Gulf of California, 99.7% of the total would have to be protected. For chaparral canyons around San Diego, 62.5% of the available area was reported to be needed to represent each species of bird, mammal, and plant at least once (Ryti 1992). These particular examples may run somewhat high since they are areas with high endemism, yet, as Noss (1987) pointed out, there just seems to be no evading the fact that a significant amount of habitat must be protected in order to represent biodiversity adequately. The reality is that a very large number of reserves seem to be necessary to secure biological diversity.

Furthermore, identifying these reserves early and in a proactive manner allows a county to plan and direct future growth to have the least impact on the environment. It also helps to avoid or minimize future conflicts with developers. Planned open space gives real estate developers and land speculators knowledge of areas with high environmental value, which they can avoid or plan around. It is important to be candid and to share all data and information. Within a community, conflicts and confrontations need to be avoided because the successful implementation of an open space plan such as this one requires the cooperation of private landowners, local developers, local governments, private nonprofit conservation organizations, and state and federal agencies.

In conclusion, when implementing local small-scale projects, GAP cannot be expected to produce the detailed, fine grain results necessary for delineating open space. It can, however, be used as a starting point, subject to refinement, field evaluation, and correction. GAP provides a critical data set that is often unavailable elsewhere for land use planning. By combining the biological and ecological knowledge in GAP with existing data sets and biological expertise, it is possible to make more informed choices about our land use activities and, hopefully, protect the legacy of billions of years of evolution. This final version appears to have satisfied our goals - a biologically defensible open space plan with a reasonable amount of land being identified in just over 2 months.

REFERENCES

Ashley, E. P. 1996. Road mortality of amphibians, reptiles, and other wildlife on the Longpoint Causeway, Lake Erie, Ontario. Canadian Field Naturalist 110(3):403-412.

Camacho, N., P. Iolavera, M. Kerins, T. Klinka, T. Kutzmark, G. Snedeker, M. Stevenson, B. Thiel, W. Turner, B. Wadsworth, F. Westerlund. 1998. Wildlife corridors and landscape linkages: an approach to biodiversity planning for Spokane County, Washington. Univ. of WA., Dept. of Urban Design and Planning, 508 Interdisciplinary Studio, Seattle. 91 pp.

Cassidy, K. M. 1997. Land cover of Washington State: Description and Management. Volume 1 in Washington State Gap Analysis - Final Report (K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, eds.). Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, 270 pp.

______, M. R. Smith, C. E. Grue, K. M. Dvornich, J. E. Cassady, K. R. McAllister, and R. E. Johnson. 1997. Gap Analysis of Washington State: an Evaluation of the Protection of Biodiversity. Volume 5 *in* Washington State Gap Analysis - Final Report (K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, eds.). Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, 192 pp.

Church, R.L., D. M. Stoms, F. W. Davis. 1996. Reserve selection as a maximal covering location problem. Biological Conservation 76:105-112.

Csuti, B. J., D. Camm, B. Downs, M. Huso, R. Hamilton, M. Kershaw, A. R. Kiester, S. Polasky, R. L. Pressey, K. Sahr, and, P. H. Williams. 1996. A comparison of reserve selection algorithms using data on terrestrial vertebrates in Oregon. Biological Conservation 80:83-97.

Edwards, Jr., T. C., E. T. Deshler, D. Foster, and G. G. Moisen. 1996. Adequacy of wildlife habitat relation models for estimating spatial distributions of terrestrial vertebrates. Conservation Biology 10(1):263-270.

Lawton, J. H., J. R. Prendergast, and B. C. Eversham. 1994. The numbers and spatial distributions of species: analyses of British data. Pages 177-195 *in* P. L. Forey, C. H. Humphries, and R. I. VaneWright, eds. Systematics and Conservation Evaluation. Clarendon Press, Oxford, England.

Metzgar, L. H., and M. Bader. 1992. Large mammal predators in the northern Rockies: grizzly bears and their habitat. Northwest Environmental Journal 8:231-233.

Naiman, R. G., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3:209-212.

Noss, R. F. 1987. Protecting natural areas in fragmented landscapes. Natural Areas Journal 7:2-13.

Prendergast, J. R., R. M. Quinn, J. H. Lawton, B. C. Eversham, and D. W. Gibbons. 1993. Rare species, the coincidence of diversity hotspots and conservation strategies. Nature 365:335-337.

Pressey, R.L., H.P. Possingham, and J.R. Day. 1997. Effectiveness of alternative heuristic algorithms for identifying indicative minimum requirements for conservation reserves. Biological Conservation 80:207-219.

Reijnen, R. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6(4):567-581.

Rosenberg, D. K., B. R. Noon, and E. C. Meslow. 1997. Biological corridors: form, function, and efficacy. BioScience 47:677-687.

Ryti, R. 1992. Effect of the focal taxon on the selection of native reserves. Ecological Applications 2:404-410.

Scott. J. M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards Jr., J. Ulliman, and R. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.

Smith, M. R., P. W. Mattocks, Jr., and K. M. Cassidy. 1997. Breeding birds of Washington state: location data and predicted distributions. Volume 4 *in* Washington State Gap Analysis - Final Report (K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, eds.). Seattle Audubon Society Publications in Zoology No. 1, Seattle, 304 pp.

Stevenson, M. R. 1998. Protecting biodiversity: applying gap analysis in Spokane County, Washington. Master's Thesis, University of Washington, Seattle, WA.

Stokland, J. N. 1997. Representativeness and efficiency of bird and insect conservation in Norwegian boreal forest reserves. Conservation Biology 11(1):101-111.

University of Washington. 1998. Wildlife corridors and landscape linkages: an approach to biodiversity planning for Spokane County, Washington. University of Washington, Department of Urban Design and Planning, 508 Interdisciplinary Studio Report, Seattle. 91 pp.

U.S. Environmental Protection Agency. 1990. Threats to biological diversity in the United States. Based on a report by: Elliott Norse, under EPA Contract #68-W8-0038, September 1990. 64 pp.

Washington Department of Natural Resources. 1998. Our changing nature: natural resource trends in Washington state. Washington Department of Natural Resources, Olympia. 75 pp.

Washington Office of Financial Management. 1998. Population trends. Washington Office of Financial Management, Olympia, WA.

Williams, C. E., and M. E. Lathbury. 1996. Economic incentives for habitat conservation on private land: applications to the Inland Pacific Northwest. Wildlife Society Bulletin 24:187-191.

Table 1. Vegetation zones for Spokane County, Washington (Cassidy 1997)

Vegetation Zone	Area in hectares (acres)	% of Spokane County
Ponderosa Pine	551,476 (1,362,146)	48.4
Palouse Grassland	341,343 (843,117)	30.0
Interior Douglas Fir	189,035 (466,916)	16.6
Three-Tip Sage	55,116 (136,137)	4.8
Grand Fir	2,034 (5,024)	<0.2
Interior Red Cedar	56 (138)	<0.1
Subalpine Fir	(Not identified by GAP)	<0.1
Totals	1,139,060 (2,813,478)	100%

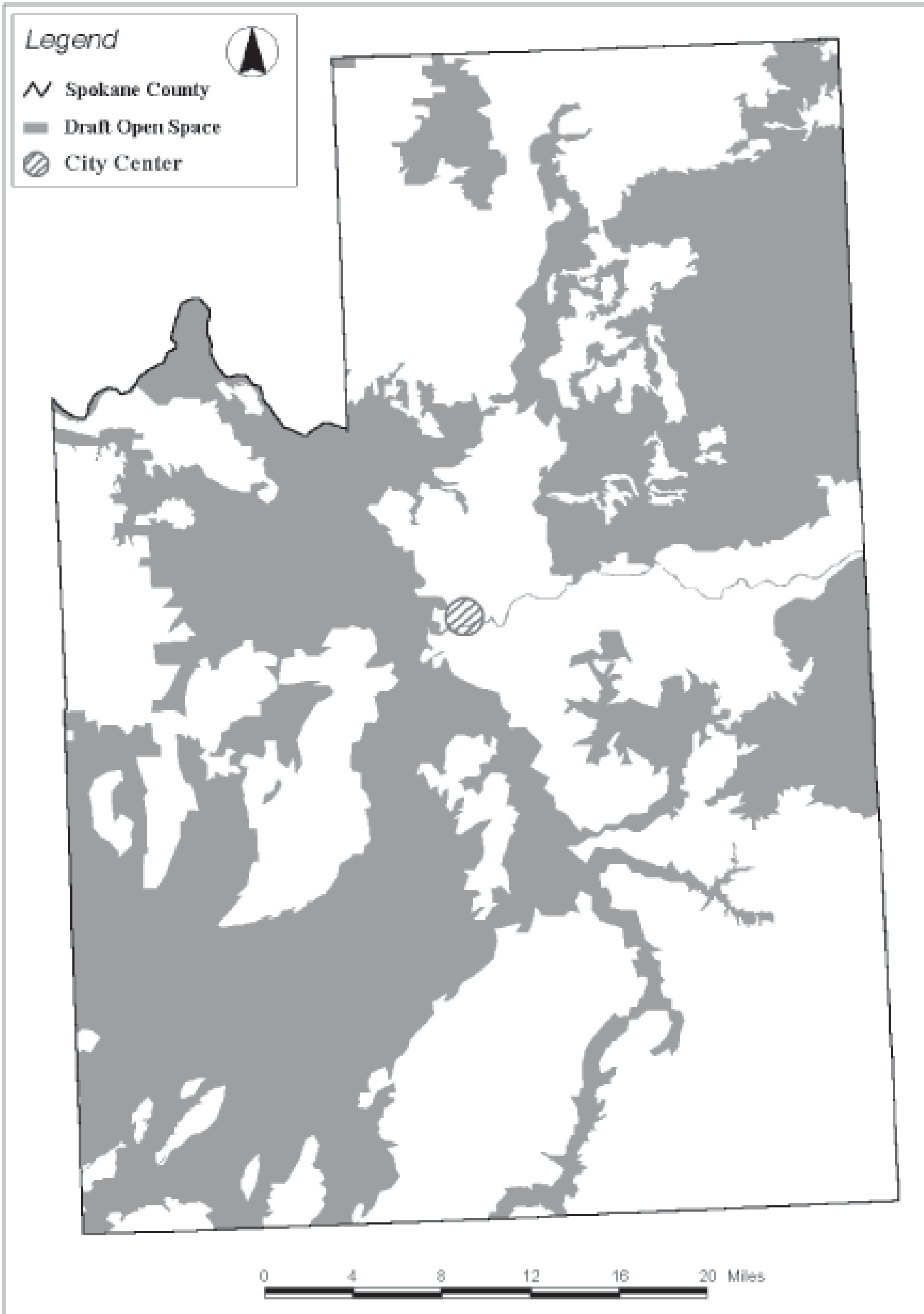
Table 2. The percentage of field-collected data sets omitted by the refined Open Space Plan (results given in % of original database points or area (if polygons)).

	Field-collected Data Sets						
	PHS	Heritage	Herp	Sensitive Plants	Heron Rookeries	Elk	Public Input
Percent of Test Data Omitted	<1% omitted (12% deer)	31% omitted	33% omitted	30% omitted	0% omitted	3% omitted	3.5% omitted

Table 3. The percentage of field-collected data sets omitted by the final Open Space Plan (results given in % of original database points or area (if polygons)).

	Field-collected Data Sets						
	PHS	Heritage	Herp	Sensitive Plants	Heron Rookeries	Elk	Public Input
Percent of Test Data Omitted	<1% omitted	7.8% omitted	7.7% omitted	7.5% omitted	0% omitted	<1% omitted	<1% omitted

Draft Open Space



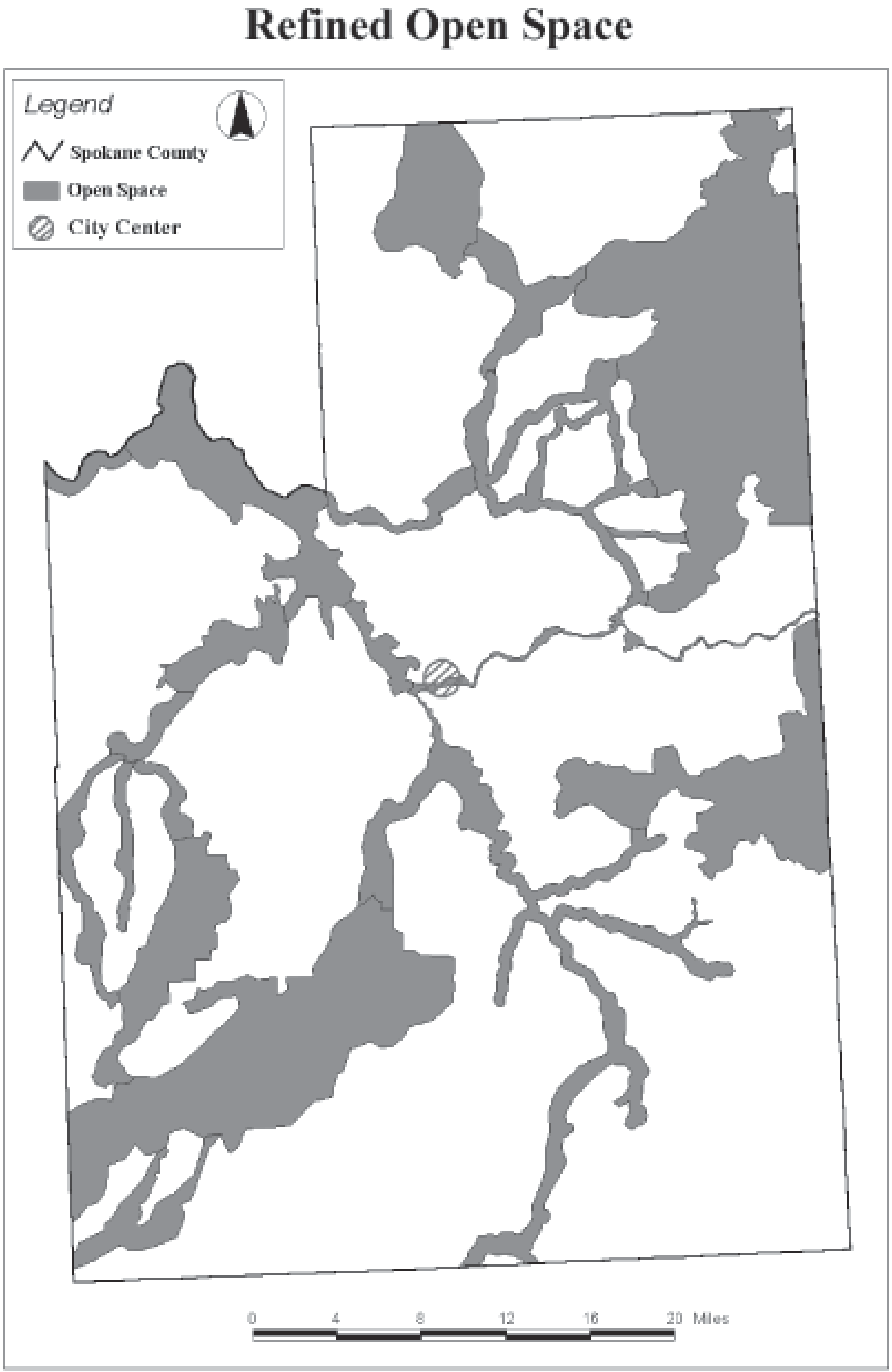


Figure 2. Refined Open Space Proposal