A Gap Analysis of the Management Status of the Vegetation of Idaho (U.S.A.)

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Abstract: *We compiled a 1:500,000-scale map of the actual vegetation of the state of Idaho from existing vegetation maps, LANDSAT MSS satellite imagery, and aerial photography. An accuracy assessment showed 92.7% of the polygons to be correctly classified. The map was digitized as a layer in a Geographic Information System (GIS) using ARC/INFO software. Land ownership was also digitized from existing maps. Ownership tracts were assigned a protection level based on opportunities provided for management for conservation of biological diversity. We then compared the vegetation and management status layers to assess the extent and degree of protection afforded to 71 vegetation and land-use categories. We identified six vegetation complexes with no protection and five vegetation complexes for which protection is less than 1000 ha each. An additional 18 vegetation types have total protection in the ranges between 1001–5000 ha and 5001–10,000 ha. Most of these 29 vegetation types are shrub-steppe complexes or conifer/steppe mosaics. Economically valuable montane forests of western redcedar, western hemlock, and grand fir, as well as subalpine woodlands and forests of mountain hemlock, are also poorly represented in protected areas. Most opportunity for increasing protection of these types lies on land managed by federal agencies. Other trends in the data include poor geographic representation, small area of individual protected occurrences, relatively good protection in Idaho but less outside of the state, and protection poor in Idaho but widespread elsewhere. The major limitation of our analysis is a lack of detail on the ecological status of vegetation types. Information on the structure of the forest types as well as data on the understory composition of the shrub-steppe complexes are lacking. Our study shows gap analysis to be an efficient and useful method of assessing the extent and degree of protection of land-cover types and associated biodiversity over an area exceeding 200,000 km^2.*

Un análisis de intervalo sobre el estado del manejo de la vegetación de Idaho

Resumen: *En este trabajo compilamos un mapa de la vegetación existente en el estado de Idaho a escala 1:500,000, a partir de mapas de vegetación existentes, imágenes de satélite Landsat MSS y fotografías aéreas. Una evaluación del error involucrado, demostró que el 92.7% de los polígonos se encontraban correctamente clasificados. El mapa fue digitalizado en un sistema de información geográfico (SIG), utilizando el software ARC/INFO. También se digitalizó la tenencia de la tierra a partir de mapas existentes. Se asignó un nivel de protección a las regiones de tenencia basado en oportunidades brindadas para el manejo para la conservación de la diversidad biológica. Después comparamos los estratos del estado de la vegetación y del manejo, para determinar la extención y el grado de protección proporcionado a 71 categorias de vegetación y de uso de la tierra. Identificamos seis complejos de vegetación sin protección y cinco complejos para los cuales la protección es de menos de 1000 ha para cada uno. Diez y ocho tipos de vegetación adicionales tienen una*

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protección total dentro de los rangos de 1001-5000 ha y 5001-10000 ha. La mayoría de estos 29 tipos de vegetación son complejos de arbustos escalonados o mosaicos de coníferas escalonadas. También se encuentran pobremente representados en áreas protegidas, los bosques de montaña económicamente valiosos del cedro rojo del oeste, del abeto americano del oeste, del abeto grande, así como también tierras de bosques subalpinos y bosques de abetos americanos de montaña. La mayor oportunidad para incrementar la protección de estos tipos de vegetación reside en el manejo de la tierra por parte de agencias federales. Otras tendencias en los datos incluyen: una pobre representación geográfica; ocurrencias protegidas individuales de área pequeña; una relativamente buena protección en Idaho, pero menos segura fuera del estado y una pobre protección en Idaho pero ampliamente distribuida en otros lugares. La mayor limitación de nuestro análisis es una falta de detalle en el estado ecológico de los tipos de vegetación. También falta de información en la estructura de los tipos de vegetación, como así también datos de la composición del sotobosque de complejos de arbustos escalonados. Nuestro estudio muestra que el análisis de intervalo es un método eficiente y útil para la evaluación de la extensión y el grado de protección de los distintos tipos de cobertura de la tierra y su biodiversidad asociada sobre un área que excede los 200,000 km^2.

Introduction

An analogy has been made between the conservation of natural resources and a three-legged stool with habitat preservation, species recovery, and sustainable use as its legs (Humphrey & Stith 1990). Which habitats should be preserved to maintain biodiversity, however, is a complex question to which a variety of answers have been proposed. In the United States, the natural heritage program system begun by The Nature Conservancy in 1975 provides a model for how detailed biological information on specific tracts of land can be managed to produce a consistent assessment of conservation priorities. In this system, biological data at the population, species, and community levels are stored in paper, map, and computer files (Jenkins 1976, 1978, 1985). The biological data is linked to a parallel data base that provides information on the management status of the specific land tracts on which these elements of biological diversity are found.

If our conservation efforts are to be successful over the long term, features of the regional landscape must also be considered (Noss 1983, 1990). Both the landscape composition (the nature and proportions of various habitats) and the landscape structure (patch area and perimeter, connectivity and fragmentation, habitat purity and interspersion, and so forth) are of critical importance to the species composition and abundance of a given landscape (Noss 1990). These factors and the ecological processes that shape them are seldom addressed in traditional approaches to population, species, and community conservation (Noss 1985, 1987).

Recent trends in conservation assessment address aspects of regional landscapes through the application of multivariate analytical techniques (see DeVelice et al. 1988). The time and expense of obtaining the detailed data required for such analyses, however, generally restricts the practical application of data-intensive analyses to regions of less than a few hundred square kilometers. In the United States, political considerations commonly support conservation analyses that focus on individual states, but only the smallest of the 50 states approach the upper end of this size limitation.

In short, what is needed is a rapid method of assessing the conservation status of biodiversity over areas ranging in area from several hundred to hundreds of thousands of square kilometers of often poorly accessible terrain. In previous papers, we proposed the use of gap analysis, in which maps of existing vegetation are used to produce maps of potential species richness. These maps are then compared to maps of land ownership and management status to assess the potential contribution of these lands to the conservation of biodiversity (Fig. 1; Scott et al. 1987, 1988, 1993).

The necessity that the vegetation maps for gap analysis should reflect actual rather than potential vegetation should be emphasized (Mueller-Dombois & Ellenberg 1974). While potential vegetation maps serve many useful purposes, a primary use of vegetation maps for gap analysis is the generation of maps of vertebrate species richness. Most species respond to the existing vegetation of an area, regardless of the vegetation the site has the potential to produce. Furthermore, while we see considerable merit in the argument that abiotic factors such as soils, surface geology, and climate should receive greater attention in general strategies to identify conservation areas (Hunter et al. 1988; Hunter 1990), we believe that an efficient strategy for terrestrial habitats begins with an accurate assessment of the existing vegetation.

The primary objective of our vegetation research was to assess the conservation status or major land-cover types in Idaho (U.S.A.). We developed a map of the actual vegetation of the state. Once this vegetation map was digitized as a layer in a geographic information system (GIS; ARC/INFO, Environmental Systems Research Institute, Inc., Redlands, California), it was easier to answer questions concerning the composition, areal extent, and distribution of the vegetative cover. In addition, when the vegetation layer was compared to the other layers of information—land ownership and management—we were able to answer questions concerning the extent and degree to which various vegetation complexes are represented in areas managed for their natural values. We also identified vegetation types that either are not protected or appear to be insufficiently protected. Our approach was similar to that of Crumpacker et al. (1988), who conducted an assessment of the conservation status of major wetland and terrestrial ecosystems in the United States. Our methods differed in that (1) we incorporated a more detailed appraisal of the level of protection; (2) we emphasized actual as opposed to potential vegetation; and (3) our study was applied at a state rather than national scale (Scott et al. 1993).

Study Area

Our study was conducted for the State of Idaho, an area of about 213,505 km^2, which lies west of the North American continental divide and extends 772 km south from the Canadian border. The maximum east-to-west distance is 491 km, although its northern section, known as the Panhandle, is less than 74 km wide.

The physiography of the state is highly variable and includes deep canyons, rugged mountains, and lava plateaus. Elevations range between 218 and 3860 meters. The climate is also highly variable. The northern portion of the state is influenced by a major storm track of Pacific air that brings abundant cloud cover, ample precipitation, moderate temperatures, and high humidity, especially during winter and spring months. Local areas of northern Idaho receive as much as 150 cm of annual precipitation. This maritime influence decreases to the south, where annual precipitation in some areas of southern Idaho is as little as 18 cm. Cloud cover is less, winters are colder, summers are hotter, and humidity is lower in southern parts of the state (Ross & Savage 1967).

A complex geologic history, with extensive glaciation and loess deposition during the Pleistocene, lava fields as young as 2000 years, and a broad diversity of bedrock lithologies, adds significantly to the natural variability of this landscape (Bonnichsen & Breckenridge 1982; Link & Hackett 1988; Chamberlain et al. 1989).

The interaction of physiography, climate, geology, and ecosystem processes (in particular, fire) on the flora has produced a complex range of vegetation types. Conifer forests, shrub steppe, and grasslands are the major natural vegetation types.

The forests of Idaho span the transition between two major floristic regions of the Rocky Mountains. North of this transition, where moisture from the Pacific Ocean moderates the climate, montane forests are dominated by evergreen conifers, including *Thuja plicata* (western redcedar) and *Tsuga heterophylla* (western hemlock). Other common tree species include *Abies grandis* (grand fir), *Larix occidentalis* (western larch), *Pinus monticola* (western white pine), *P. ponderosa* (ponderosa pine), and *Pseudotsuga menziesii* (Douglas fir) (Daubenmire 1943, 1952; Daubenmire & Daubenmire 1968; Cooper et al. 1987).

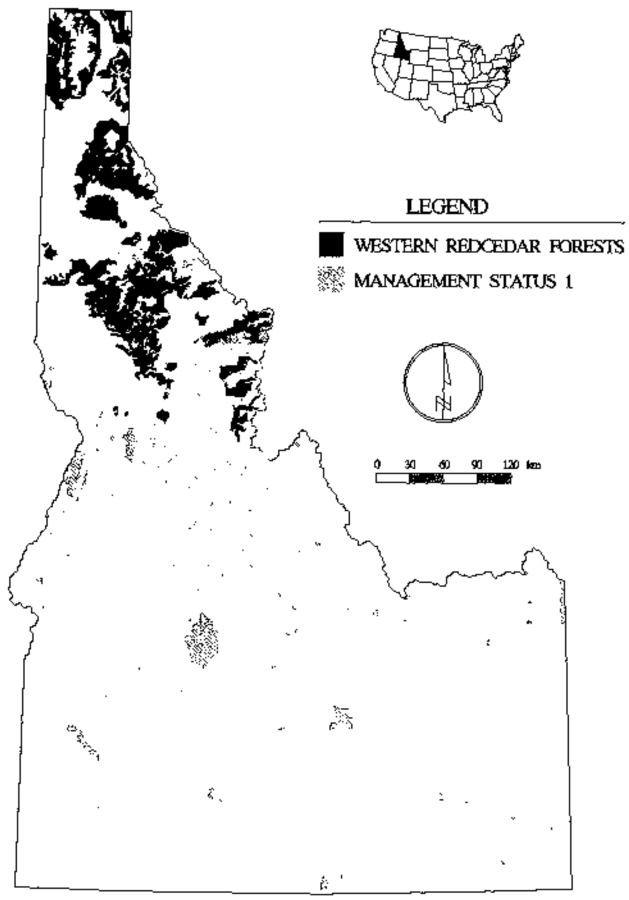

*Figure 1. The comparative distribution of conifer forests in which western redcedar (*Thuja plicata*) is a codominant and protected areas of management status 1 in Idaho.*

In southern Idaho, the montane forests are comprised primarily of Douglas fir, *Pinus contorta* (lodgepole pine), and *P. flexilis* (limber pine); neither western redcedar nor western hemlock are present. Grand fir and ponderosa pine extend south only along the western edge of the state. Similar differences exist among understory shrubs and herbs between the montane forests of southern and northern Idaho (Daubenmire 1943; Steele et al. 1981, 1982).

Subalpine forests also illustrate the effects of the Pacific storm track, with *Tsuga mertensiana* (mountain hemlock) and *Larix lyallii* (Lyall's larch) both reaching the southern limit of their ranges in the Rocky Mountains north of the transition. *Abies lasiocarpa* (subalpine fir), *Picea engelmannii* (Engelmann spruce), and *Pinus albicaulis* (whitebark pine) are ubiquitous at higher elevations in Idaho, but the latter two species are particularly abundant in the drier subalpine forests of southern Idaho. As in the montane forests, many differences in understory species occur between the subalpine forests of northern and southern Idaho.

Steppe vegetation below the lower treeline also differs north and south of the transition zone. The chief contrast is the absence of woody species of *Artemisia* (sagebrush) in the Palouse Grasslands of northern Idaho (Daubenmire 1970; Tisdale 1986) compared to the numerous species and infraspecific taxa of *Artemisia* in the cold deserts of southern Idaho (Tisdale & Hironaka 1981; Hironaka et al. 1983).

A wide variety of bunchgrasses may also occur in the steppe vegetation. Important species include *Festuca idahoensis* (Idaho fescue), *Agropyron spicatum* (bluebunch wheatgrass), *Stipa comata* (needle-and-thread grass), *Sitanion hystrix* (bottlebrush squirreltail), and *Poa secunda* (Sandberg bluegrass). In many areas, excessive livestock grazing has resulted in the replacement of the native bunchgrasses by annual grasses.

Although conifer forests, shrub steppe, grasslands, and the complex boundaries among them comprise the bulk of the natural vegetation of Idaho, a wide variety of other vegetation types also occur. Some of the more distinctive types include salt desert shrub, brushfields, juniper woodlands, cottonwood riparian forests, and alpine tundra (Table 1).

Methods

The methodology used to prepare a vegetation map is determined by the purposes for which the map will be used (Kuchler 1956, 1967, 1988*a*), although both time and budget may impose constraints. A vegetation map prepared for the gap analysis of biological diversity must portray the vegetation in sufficient detail to answer questions about the areal extent, distribution, and protection status of the major types. The vegetation map must also serve as a tool for developing and refining range maps for vertebrates and other species to be included in the analysis (Scott et al. 1993).

This investigation was a pilot study for modeling biodiversity over large areas. Due to budget and time constraints, we chose to compile a vegetation map from existing sources at a scale of 1:500,000. All source maps used were at a larger scale. We took the traditional compilation steps of obtaining existing map coverage, selecting a classification, and translating the source-map classifications into the new classification (Kuchler 1988*b*). The classification in Table 1 includes 71 types, most of which are vegetation complexes (see Craighead et al. 1988) with names based on the dominant canopy species. This classification, while of floristic importance, this at a more refined level than is needed for modeling vertebrate distributions.

Two-thirds of the state is owned by the federal government, and federal land management agencies were the best source of existing vegetation maps. Lands administered by the Forest Service were mapped using timber-type maps (1:31,680) prepared during the period 1950–1970. Vegetation maps at various scales were available in recent planning documents for lands administered by the Bureau of Land Management.

The large scale of most source maps required a great deal more generalization than our map scale did. The source maps were photoreduced to 1:500,000, and the polygon boundaries were traced onto clear acetate overlays of each county using a minimum mapping unit (MMU) of 260 ha. This MMU was chosen because it represented a reasonable degree of resolution for a map at this scale. The county maps were edge-matched and combined into three overlays that covered the entire state. These overlays were manually digitized into the GIS and edge-matched. Areas not covered by local vegetation maps and major areas of recent changes in land-use or land-cover were mapped by visual interpretation of false-color composites of Landsat MSS imagery and aerial photography. We chose standard classifications for the majority of our mapping units. Forest types were mapped using the cover types defined by the Society of American Foresters (1980), although modifications were made to the nomenclature of each type to indicate both major and minor tree species. Nonforest types were mapped according to the classification developed for southern Idaho by Hironaka et al. (1983), but lack of information on the bunchgrasses present restricted our classification to the shrub layer. Furthermore, the tendency of shrub types to occur in complex mosaics corresponding to soil type made it necessary for us to map them at a higher level than the series described by Hironaka et al. (1983). Additional types were based on published literature, where available, or on unpublished information in the files of the Idaho Natural Heritage Program.

Mapping actual vegetation remains a fundamental activity of gap analysis projects in more than 30 states, but we emphasize that the methods described here for the Idaho pilot project have been supplanted by hybrid approaches that include digital classification of LANDSAT Thematic Mapper Imagery (Scott et al. 1993). Multiple types of ancillary information, such as low-altitude airborne videophotography (Graham 1993), are used in labeling map polygons. Current gap-analysis vegetation maps have 100-ha minimum mapping units for upland vegetation and 40-ha minimum mapping units for wetlands. Habitat classifications, however, are generally more broadly defined than those used in the Idaho study. Although our current vegetation mapping methods begin with more-complete information coverage and offer higher resolution, the map described here contains ample information for an initial assessment of the distribution and conservation status of Idaho's vegetation.

Land-ownership and some general management-status information was digitized directly from 1:100,000-scale surface management status maps available from the Bureau of Land Management. Boundaries for special management areas not appearing on these maps (research natural areas, areas of critical environmental concern, etc.) were obtained from the map files of the Idaho Natural Heritage Program. All lands were assigned to one of four management status classes:

(1) An area with an active management plan in operation that is maintained in its natural state and within which natural disturbance events are allowed to proceed without interference or are mimicked through management. Most national parks, Nature Conservancy preserves, some wilderness areas, Audubon Society Preserves, some national wildlife refuges, and Research Natural Areas are included in this class.

(2) An area that is generally managed for its natural values but may receive use that degrades the quality of natural communities that are present. Most wilderness areas, national wildlife refuges managed for recreational uses, and Bureau of Land Management Areas of Critical Environmental Concern are included in this class.

(3) This class encompasses most nondesignated public lands, including Forest Service, Bureau of Land Management, and state park lands. Legal mandates prevent permanent conversion to anthropogenic habitat types (with some exceptions, such as tree plantations) and confer some protection to populations of species federally listed as endangered or threatened and candidates for listing.

(4) All land in public or private ownership without an existing easement or irrevocable management agreement that maintains native species and natural communities and that is managed primarily or exclusively for intensive human activity. Urban, residential, and agricultural lands, public buildings and grounds, and transportation corridors are included.

The assessment of map accuracy is fraught with difficulties and seldom discussed. A major complication is the problem of evaluating the accuracy of a map at a scale of 1:500,000, where a map resolution of 0.5 mm translates to 250 meters on the ground. The U.S. Geological Survey has established a National Map Accuracy Standard of 0.02 inches, which at a scale of 1:500,000 corresponds to about 254 meters. Thus, a given polygon boundary meets this standard if it falls within 127 meters of the actual boundary. The limitation of this approach is that while it works well for discrete boundaries, vegetation boundaries are generally diffuse and can often be difficult to define precisely even on the ground. While boundary accuracy remains a concern, it should also be recognized that vegetation boundaries are dynamic and may shift significantly over relatively short time spans (Hunter et al. 1988). In this respect, vegetation boundaries serve only as temporal markers of significant points along environmental gradients.

For these reasons, our assessment emphasized the verification of the classification assigned to the polygon rather than the accuracy of boundary placement. We randomly selected 150 circular sample plots, each of which was 1.6 km in diameter. For each sample plot, we obtained aerial photography. In general, our preference was for the most recent photos of normal color and moderate scale (1:10,000–1:40,000), taken in summer. In some cases, older photos were used in order to obtain normal color at a larger scale. Some black-and-white and color infrared photography was also used. The range of dates was from 1975 to 1988.

Using the worst-case scenario (proportion of correct vegetation types where $p = 0.50$ and $n = 150$ sample plots) our estimated proportion, p, had a bound on the error of estimation equal to ± 0.04 (4%). After the aerial photointerpretation was complete on the 150 sample plots, 139 were found to have matched the vegetation type(s) where they were located. Thus, the Idaho map was found to be 92.7% correctly classified (actual $p = 0.39$, with a bound on the error of estimation equal to ± 0.04).

Of the 11 sample plots that were incorrectly classified, three were in high-elevation areas where the boundary between subalpine and alpine zones is difficult to determine. The remaining eight were within large vegetation polygons where elevation and aspect changes were apparently not taken into account. Of the 150 sample plots, 17 fell on the boundaries between two vegetation types, suggesting that the boundaries between types are not sharply defined. For these points, the classification was considered correct if either of the boundary polygons agreed with the sample point.

Results and Discussion

The 71 vegetation types in Table 1 are organized into 10 groups that portray a general ecological gradient from alpine communities, through various subalpine and montane forest types, to woodlands, nonforest types, and cultural landscapes more characteristic of lower elevations. Most of the individual types within these 10

Table 1. Total area and extent of protection at levels 1 and 2 of 71 vegetation complexes and land-use types in Idaho.[1]

			Protection Level 1		
Vegetation Complex or Land-Use Type	*Total Hectares*	*Percentage of State*	*Total Hectares*	*Percentage of Total*	*Freq.*
Alpine					
alpine communities	86,654	0.39	9,738	11.24	3
Subalpine Parklands					
subalpine fir–mountain hemlock[2]	16,431	0.08	—	—	—
whitebark pine–subalpine fir	200,517	0.93	21,100	10.52	15
subalpine fir–Engelmann spruce	323,820	1.50	67,827	20.95	21
subalpine fir–whitebark pine	231,689	1.07	93,331	40.28	19
	772,457	3.57	182,258	23.59	55
Subalpine Forests					
subalpine fir–Douglas fir–quaking aspen	81,865	0.38	93	0.11	1
subalpine fir–lodgepole pine	430,969	1.99	223,447	51.85	43
mountain hemlock–subalpine fir[2]	69,693	0.32	1,685	2.42	3
Engelmann spruce–subalpine fir	66,831	0.31	37,035	55.42	4
lodgepole pine–quaking aspen-subalpine fir[2]	34,139	0.16	—	—	—
lodgepole pine	204,019	0.94	25,518	12.51	12
lodgepole pine–subalpine fir–Engelmann spruce	279,093	1.29	93,392	33.46	42
	1,166,609	5.39	381,170	32.67	105
Montane Forests					
western larch–Douglas fir[2]	152,410	0.70	1,630	1.07	1
Douglas fir–western larch[2]	358,854	1.66	5,802	1.62	6
Douglas fir–Engelmann spruce[2]	13,277	0.06	1,371	10.32	1
western redcedar–western hemlock[2]	560,529	2.59	1,598	0.29	12
grand fir–western redcedar[2]	264,938	1.13	1,431	0.59	6
western redcedar–grand fir–Douglas fir	286,508	1.42	12,920	4.22	18
western redcedar–grand fir	38,787	0.18	18,228	46.99	57
Douglas fir–grand fir–western redcedar	100,060	0.46	50,838	50.81	49
grand fir–Douglas fir[2]	240,965	1.11	5,411	2.25	17
Douglas fir–grand fir	240,873	1.11	39,151	16.25	61
Douglas fir–limber pine–whitebark pine[2]	94,038	0.43	919	0.98	6
Douglas fir	439,140	2.03	140,753	32.05	39
Douglas fir–lodgepole pine	1,056,330	4.88	318,630	30.16	79
lodgepole pine–mixed conifer[2]	114,561	0.53	6,763	5.90	8
lodgepole pine–Douglas fir–quaking aspen	347,943	1.61	70,605	20.29	31
lodgepole pine/brushfields	86,507	0.40	62,765	72.55	6
ponderosa pine–lodgepole pine[2]	322,689	1.49	5,037	1.56	6
ponderosa pine–Douglas fir	578,364	2.67	132,807	22.96	39
Douglas fir–ponderosa pine	376,094	1.74	107,555	28.60	62
	5,672,224	26.19	984,214	17.35	504
Montane Forest–Steppe Transitions					
Douglas fir–limber pine/montane brush mosaic[2]	57,959	0.27	—	—	—
Douglas fir–aspen/montane brush or sagebrush[2]	442,867	2.04	2,752	0.62	11
lodgepole pine–quaking aspen–mountain brush	143,000	0.66	471	0.33	10
ponderosa pine/grassland or montane sagebrush	182,837	0.84	10,197	5.58	19
ponderosa pine–Douglas fir/grassland	159,690	0.74	29,969	18.77	33
mountain sagebrush/forest mosaic		4.32	7,626	0.81	22
	1,922,438	8.88	51,015	2.65	95
Montane Shrubfields					
mountain brush[2]	388,238	1.79	7,048	1.82	30
brushfields	287,840	1.33	63,192	21.95	21
	676,078	3.12	70,240	10.39	51
Foothills and Plains Woodlands					
limber pine/greasewood[2]	1,056	0.00	—	—	—
western juniper/low sagebrush mosaic[2]	66,704	0.31	—	—	—
western juniper/mountain sagebrush[2]	35,485	0.16	—	—	—
Utah juniper/mountain sagebrush[2]	62,507	0.29	18	0.03	1
Utah & Rocky Mountain juniper/big sagebrush[2]	132,072	0.61	3,489	2.64	9
singleleaf pinyon–Utah juniper[2]	10,351	0.05	4,761	45.99	2
limber pine/bitterbrush[2]		0.04	6,093	84.54	2
	316,340	1.46	15,171	4.80	14

Table 1. Continued.

Protection Level 2			*Protection Levels 1 & 2*		
Total Hectares	*Percentage of Total*	*Freq.*	*Total Hectares*	*Percentage of Total*	*Freq.*
1,144	1.32	2	10,882	12.56	5
—	—	—	—	—	—
39,430	19.66	5	60,530	30.18	20
—	—	—	67,827	20.95	21
2,888	1.25	13	96,219	41.53	32
42,318	5.48	18	224,576	29.07	73
20,788	25.39	4	20,881	25.50	5
3,559	0.83	1	227,006	52.68	44
—	—	—	1,685	2.42	3
—	—	—	37,035	55.42	4
3,271	9.58	2	3,271	9.58	2
1,882	0.92	1	27,400	13.43	13
—	—	—	93,392	33.46	42
29,500	2.53	8	410,670	35.20	113
—	—	1	1,630	1.07	2
273	0.08	2	6,075	1.70	8
—	—	—	1,371	10.32	1
95	0.02	3	1,693	0.31	15
1,041	0.43	6	2,472	1.02	12
—	—	—	12,920	4.22	18
—	—	—	18,228	46.99	57
635	0.63	2	51,473	51.44	51
2,307	0.96	5	7,718	3.21	22
3,470	1.44	7	42,621	17.69	68
—	—	—	919	0.98	6
700	0.16	2	141,453	32.21	41
21,822	2.07	9	340,452	32.23	88
—	—	—	6,763	5.90	8
53,441	15.36	7	124,046	35.65	38
—	—	—	62,765	72.55	6
1,125	0.35	6	6,162	1.91	12
574	0.10	7	133,381	23.06	46
3,216	0.85	4	110,771	29.45	66
88,699	1.56	69	1,072,913	18.91	565
—	—	—	—	—	—
1,730	0.39	5	4,482	1.01	16
9,537	6.67	2	10,008	7.00	12
201	0.11	7	10,398	5.69	26
5,792	3.63	8	35,761	22.40	41
49,263	5.26	6	56,889	6.07	28
66,523	3.46	28	117,538	6.11	113
1,230	0.32	1	8,278	2.14	31
—	—	—	63,192	21.95	21
1,230	0.18	1	71,470	10.57	52
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	18	0.03	1
4,439	3.36	9	7,928	6.00	18
—	—	—	4,761	45.99	2
—	—	—	6,903	84.54	2
4,439	1.40	9	19,610	6.20	2

Table 1. Continued.

Vegetation Complex or Land-Use Type	Total Hectares	Percentage of State	Protection Level 1 Total Hectares	Protection Level 1 Percentage of Total	Protection Level 1 Freq.
Shrub Steppe and Grasslands					
montane sagebrush and antelope bitterbrush mosaic	145,373	0.67	64	0.04	1
threetip and mountain sagebrush mosaic[2]	83,211	0.38	315	0.38	2
mountain and low sagebrush mosaic	1,335,387	6.17	6,895	0.52	23
low and mountain sagebrush mosaic	135,294	0.62	52	0.04	2
low and black sagebrush mosaic[2]	146,082	0.67	153	0.10	2
low and fringed sagebrush mosaic[2]	12,945	0.06	12	0.10	2
low and big sagebrush mosaic	413,004	1.91	22,508	5.45	10
early low sagebrush	97,051	0.45	13,758	14.18	2
black sagebrush/western juniper mosaic[2]	43,447	0.20	8,547	19.67	3
big sagebrush on lava fields	221,428	1.02	14,456	6.53	5
big and low sagebrush mosaic	2,276,376	10.51	28,796	1.26	32
salt desert shrub	459,169	2.12	1,948	0.42	8
canyon grasslands	189,968	0.88	16,482	8.68	44
canyon shrub	117,981	0.54	19,647	16.65	7
sand dune communities[2]	17,049	0.08	5,515	32.35	4
	5,693,765	26.29	139,148	2.44	147
Riparian and Wetland Types					
lodgepole pine floodplain riparian[2]	4,536	0.02	—	—	—
black or narrowleaf cottonwood floodplain riparian	45,020	0.21	10,928	24.27	6
willow floodplain riparian	32,747	0.15	2,576	7.87	1
bulrush–cattail marshes	52,065	0.24	—	—	—
open water	154,195	0.71	5,548	3.60	4
	288,563	1.33	19,052	6.60	11
Cultural Landscapes					
agricultural crop and pastureland	3,606,140	16.65	29,523	0.82	59
annual grasslands	686,289	3.17	737	0.11	3
perennial bunchgrass seedings	493,794	2.28	1,336	0.27	4
recent timber harvest areas	210,700	0.97	780	0.37	7
urban and industrial	66,356	0.31	—	—	—
	5,063,279	23.38	32,376	0.64	73
	21,656,407	100.00	1,884,382	8.70	1,058

groups are also ordered to represent subportions of this overall ecological gradient. Slightly more than half of the state is covered by either montane forest or shrub-steppe and grasslands. Nearly one-quarter has been converted to cultural landscapes. The remaining area is comprised of transitional environments adjacent to the lower and upper treelines, alpine environments, and wetlands and riparian ecosystems (Fig. 2).

The overall extent of conservation-related management for vegetation in Idaho is skewed toward higher elevations, with total management status 1 and 2 exceeding 35% in subalpine forests and 29% in subalpine parklands. Alpine communities, montane forests, and riparian/wetland types also have relatively high values of overall protection, although protection for wetlands is probably overestimated for reasons related to scale. The extent of protection is substantially lower in montane shrubfields, montane forest-steppe transitions, foothills and plains woodlands, and shrub-steppe and grasslands. A general appraisal of the extent and degree of protection afforded to nine higher-level groupings of natural vegetation (cultural landscapes are excluded) by the existing network of managed areas is shown in Figure 3.

The degree of management for natural values also varies among the 10 groups. The percentage of montane forests, subalpine parklands, and subalpine forests in areas of management status 1 is 17%, 24%, and 33%, respectively. The amounts are substantially lower for all remaining types and less than 5% in foothills and plains woodlands, forest-steppe transitions, and shrub-steppe and grassland complexes (Table 1).

Two size classes of areas in management status 1 and 2 predominate in Idaho, those smaller than 100 ha and those between 100 and 1000 ha (Fig. 4). Less than one-third of the existing reserves exceed 500 ha, only about 20% are larger than 1000 ha, and less than 6% are greater than 10,000 ha. All of the smaller management areas are likely to require intensive management in or-

Table 1. Continued.

Protection Level 2			*Protection Levels 1 & 2*		
Total Hectares	*Percentage of Total*	*Freq.*	*Total Hectares*	*Percentage of Total*	*Freq.*
11,221	7.72	6	11,285	7.76	7
985	1.18	2	1,300	1.56	4
11,006	0.82	13	17,901	1.34	36
—	—	—	52	0.04	2
—	—	—	153	0.10	2
—	—	—	12	0.10	2
—	—	—	22,508	5.45	10
—	—	—	13,758	14.18	2
—	—	—	8,547	19.67	3
1,389	0.63	2	15,845	7.16	7
215,882	9.48	31	244,678	10.74	63
19,027	4.14	23	20,975	4.56	31
17,058	8.98	7	33,540	17.66	51
5,026	4.26	11	24,673	20.91	18
1,200	7.04	5	6,715	39.39	9
282,794	4.97	100	421,942	7.41	247
—	—	—	—	—	—
3,298	7.33	11	14,226	31.60	17
8,897	27.17	7	11,473	35.03	8
19,105	36.69	7	19,105	36.69	7
12,338	8.00	32	17,886	11.60	36
43,638	15.12	57	62,690	21.72	68
37,188	1.03	146	66,711	1.85	205
5,117	0.75	15	5,854	0.86	18
6,658	1.35	36	7,994	1.62	40
296	0.14	9	1,076	0.51	16
95	0.14	2	95	0.14	2
49,354	0.97	208	81,730	1.61	281
609,639	2.81	492	2,494,021	11.52	1,540

[1] *The organization of the chart is along a general ecological gradient from high- to low-elevation ecosystems. Frequency refers to the number of polygons (or portions of polygons) of a given type falling within the noted levels of protection.*
[2] *Complexes with no or only limited protection in Idaho.*

der to maintain self-sustaining populations of large carnivores and other vertebrates (Schonewald-Cox 1983; Schonewald-Cox et al. 1991). For large herbivores, areas larger than 50,000 ha may be adequate with active management, while smaller mammals may occur in self-sustaining populations within areas of about 50,000 ha (East 1981). The minimum dynamic area required for natural regulation of vegetation and ecosystems by landscape disturbances such as fire far exceeds the size of most reserves (Romme 1982; Baker 1989), and active management is required to protect their biodiversity (Niering 1987; Brussard 1991).

Conservation Needs in Idaho

Based on the results of our analysis, we have identified a number of conservation priorities in Idaho (Table 2). These are coarse-filter needs based on the assumption that vegetation is a major integrator of both biotic and abiotic diversity (Specht 1975; Austin 1991).

Vegetation Complexes Not Found in Management Status Classes 1 and 2

Six vegetation types are not represented in management areas of category 1 or 2. One of these is a highly localized complex. A second is a riparian type that commonly occurs in patches smaller than our minimum mapping unit; therefore, its protection status may be underestimated in our analysis. The remaining types include subalpine parklands of northern Idaho in which mountain hemlock is important, western juniper (*Juniperus occidentalis*) forests and woodlands restricted to southwestern Idaho, and a Douglas fir–limber pine/mountain brush mosaic most common in southeastern Idaho. The latter complex is maintained by fire, so management policy is more important than protective des-

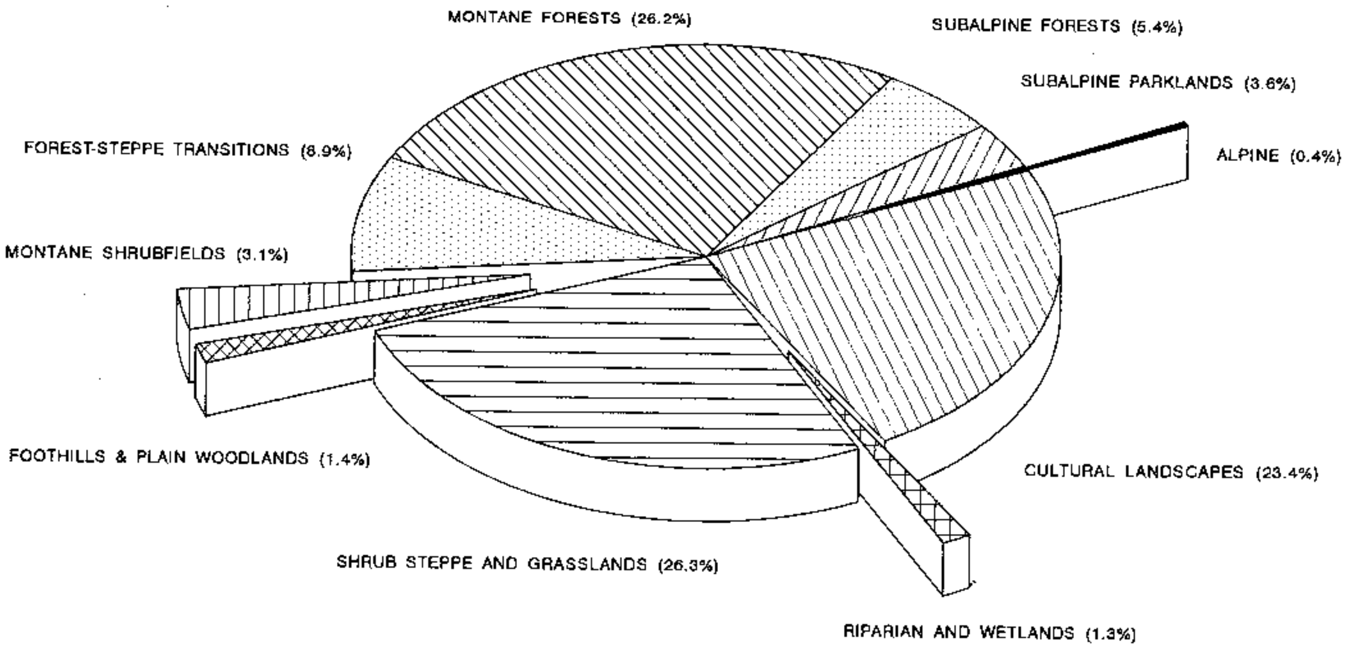

Figure 2. Relative composition of vegetation in Idaho based on vegetation map compiled for gap analysis of biodiversity protection.

ignation per se for the persistence of this type on the landscape. Federal agencies entrusted with management responsibilities for all but the juniper types include the Forest Service and the Bureau of Land Management. The latter agency is the sole federal agency with jurisdiction over the juniper woodlands.

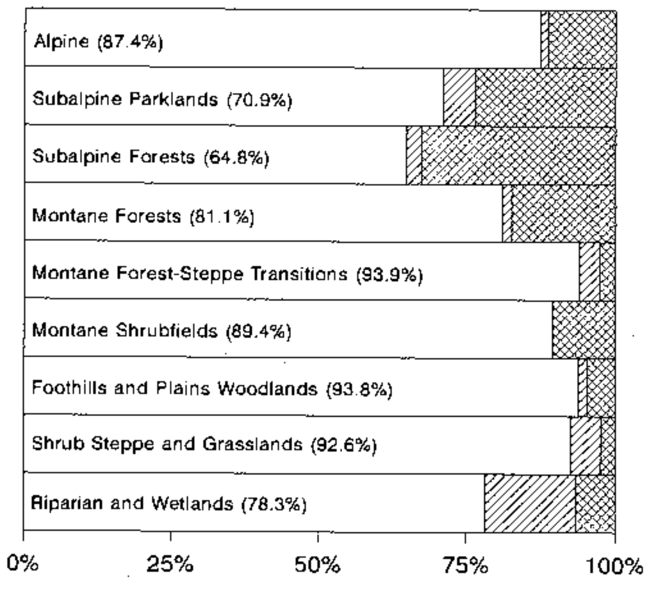

Figure 3. Relative proportions of Idaho vegetation types within areas of management status 1 and 2. The chart is arranged according to a general ecological gradient from high to low elevation. Percentages refer to the proportion of each type with inadequate protection. See text for definition of management status classes. ▩ Level 1, ▨ Level 2, □ other.

Vegetation Complexes for which Total Existing Representation in Category 1 and 2 Management Areas is Less than 1000 ha

Five vegetation types are represented by less than 1000 ha in management areas of categories 1 and 2. Four of these have total protected areas of less than 200 ha, including three low-sagebrush mosaics in which mountain sagebrush (*Artemisia tridentata* ssp. *vaseyana*), black sagebrush (*A. nova*), or (less commonly) fringed sagebrush (*A. frigida*) communities co-occur. The fourth type is a forest and woodland of Utah juniper (*Juniperus osteosperma*). The fifth type is an open-forest complex of Douglas fir, limber pine, and whitebark pine that is restricted to the limestone mountains of east-central Idaho. The primary federal agency with administration over the latter complex is the Forest Service. The remaining four types are under the jurisdiction of the Bureau of Land Management.

Vegetation Complexes for which Total Existing Representation in Category 1 and 2 Management Areas Is Between 1001 and 5000 ha

Nine types of vegetation have a total protected area in the range of 1001–5000 ha. Three of these are primarily dependent upon fire management policy. Two others are mesic forests in which western redcedar is codominant with either western hemlock or grand fir. Two additional forest types are also included, an uncommon Douglas fir–Engelmann spruce complex and a subalpine

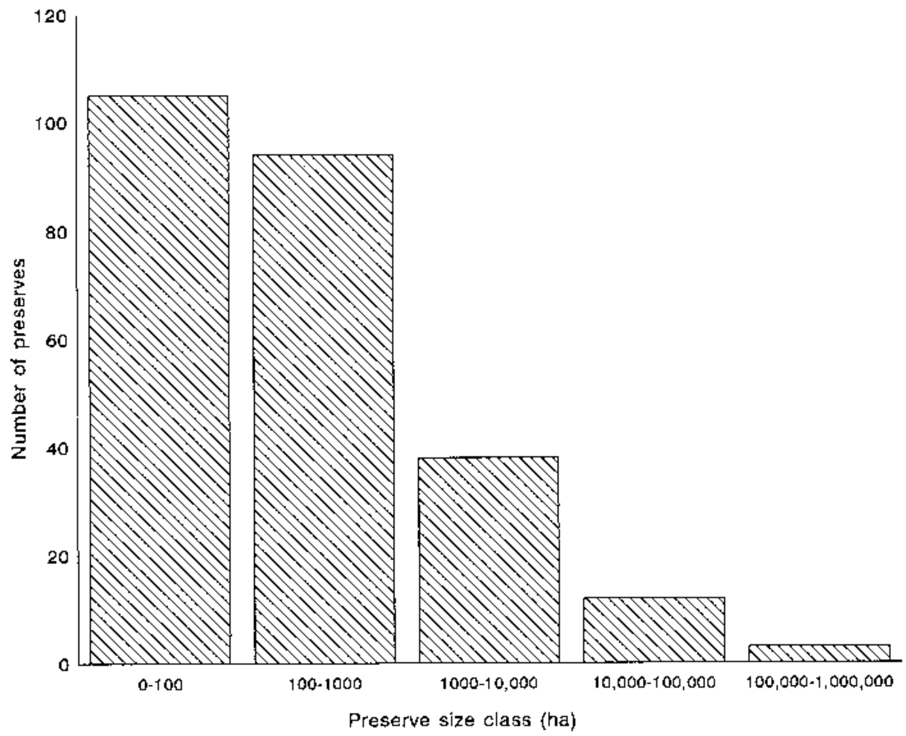

Figure 4. Size-frequency distribution of 262 existing preserves in Idaho. Included are all areas of management status 1 or 2. These data are based on the digitized land-ownership layer. See text for definition of management status classes.

forest of mountain hemlock and subalpine fir. All of the forests but the latter are the primary responsibility of the Forest Service. The latter is the joint responsibility of the Forest Service and the Bureau of Land Management. The final two types are a mosaic of threetip sagebrush (*Artemisia tripartita*) and mountain sagebrush and a woodland of singleleaf pinyon (*Pinus monophylla*) and Utah juniper. Both the Forest Service and the Bureau of Land Management administer the sagebrush type. Despite their small total area, nearly half of the pinyon-juniper woodlands are currently protected in a joint administrative complex of the Forest Service, Bureau of Land Management, and Idaho Department of Parks and Recreation. The protective designation is primarily related to the historical importance of the area, known as the City of Rocks. Ensuring that conservation needs are addressed in the management policies of the area remains an important priority.

Vegetation Complexes for which Total Existing Representation in Category 1 and 2 Management Areas Is Between 5001 and 10,000 ha

Nine more types of vegetation have a total protected area in the range of 5001–10,000 ha. Two of these are fire-dependent complexes amenable to management policies that favor their persistence. A third is a disturbance type most of which is indicative of historic placer or hydraulic mining. A small portion of a natural occurrence of this type occurs on glacial outwash sediments in northern Idaho, but this area has been extensively logged. Of the remaining types, one is a dry forest complex of grand fir and Douglas fir. The Forest Service is the primary federal agency responsible for the administration of these forest complexes. Two additional types include mountain brush communities and a black sagebrush–western juniper mosaic. Mountain brush communities in Idaho are the shared responsibility of the Forest Service and the Bureau of Land Management. The sagebrush type is restricted to southwestern Idaho, where the Bureau of Land Management has sole management responsibility. The final two types in this category include sand-dune communities, which have a relatively high degree of protection, and a unique limber pine–bitterbrush (*Purshia tridentata*) type that lies predominantly within the Craters of the Moon National Monument, administered by the National Park Service.

The above categories include 29 of the 71 types mapped during our study. They represent, with the exceptions noted, our assessment of current conservation priorities in the vegetation of Idaho. This should not be taken to mean, however, that the 37 vegetation types and five cultural types that remain are of no conservation interest.

Table 2. Vegetation types with no protection, or only limited protection in Idaho. The total area, protected area and percentage protected (in parentheses), and the number of protected polygons is given. Definitions of protection are provided in the text. All area values are in hectares.

Idaho Vegetation Types not Represented in Areas with Management Status 1 or 2
- limber pine/greasewood[1]
- lodgepole pine floodplain riparian[2]
- subalpine fir–mountain hemlock
- western juniper/mountain sagebrush
- Douglas fir–limber pine/mountain brush mosaic
- western juniper/low sagebrush mosaic

Idaho Vegetation Types with Less than 1000 ha in Areas with Management Status 1 or 2
- Utah juniper/mountain sagebrush
- low and mountain sagebrush mosaic
- low and black sagebrush mosaic
- low and fringed sagebrush mosaic
- Douglas fir–limber pine–whitebark pine

Idaho Vegetation Types with between 1001 and 5000 ha in Areas with Management Status 1 or 2
- western redcedar–western hemlock
- lodgepole pine–quaking aspen–subalpine fir[3]
- Douglas fir–quaking aspen/mountain brush or sagebrush[3]
- grand fir–western redcedar
- western larch–Douglas fir[3]
- threetip and mountain sagebrush mosaic
- mountain hemlock–subalpine fir
- Douglas fir–Engelmann spruce
- singleleaf pinyon–Utah juniper

Idaho Vegetation Types with between 5001 and 10,000 ha in Areas with Management Status 1 or 2
- Douglas fir–western larch[3]
- ponderosa pine–lodgepole pine[4]
- mountain brush
- grand fir–Douglas fir
- lodgepole pine–mixed conifer[3]
- Utah and Rocky Mountain juniper/big sagebrush
- black sagebrush/western juniper mosaic
- sand dune communities
- limber pine/bitterbrush

[1] *Highly localized type.*
[2] *Priority status is questionable. More common than mapped because patch size is generally smaller than minimum mapping unit. Needs to be assessed at finer scale.*
[3] *A mosaic primarily influenced by fire. As noted in the text, the persistence of such types in the landscape depends more on fire management policy than protective designation.*
[4] *Primarily a disturbance type, caused by extensive placer and hydraulic mining. A small area in northern Idaho is underlain by well-drained glacial outwash. Most of this area has been logged.*

Details concerning the management status of the remaining vegetation complexes are given in Table 1. The following trends in these data deserve emphasis.

Poor Geographic Representation

Alpine communities provide a good example of the trend toward poor geographic representation. Despite the fact that nearly 25% of their total area lies within areas of management status 1 and 2, the geographic distribution of protected areas of this type is poor. Furthermore, nearly 90% of the total area lies within only two of the five protected areas (Table 1), indicating that the remaining three areas are of such small size that their long-term viability is called into question.

Good Geographic Representation but Small Area of Individual Protected Occurrences

The mesic forest type, western redcedar–grand fir, provides a good example of this pattern of good graphic representation but small area of protection. Despite the large number of protected occurrences, the total area is low and mean protected patch size is only slightly greater than 300 ha (Table 1). Nevertheless, our results show that this is nearly half of the western redcedar–grand fir type. This pattern is repeated in several mesic forest types. A more detailed analysis of the mesic forests of Idaho may clarify the picture.

Relatively Good Protection in Idaho but Less Outside the State

Our analysis shows that the xeric forest and forest-steppe transitions, generally characterized by the presence of ponderosa pine, have total extent of protection in the 20 to 30% range (Table 1). This is due to large reserves that encompass major portions of the canyons of the Salmon and Snake Rivers. Because of the rugged and remote canyons in which these forests occur, their ecological condition is quite good. Throughout most of the western United States, however, ponderosa pine forests are in poor ecological condition due to high grading, fire suppression, and other factors, and they may be one of the most threatened of the major western forest types (R. F. Noss, personal communication). Thus, while additional protection for ponderosa pine forests may not be one of the highest conservation priorities in Idaho, the same may not be true in most other western states. The implementation of gap analysis at larger scales will provide a means of identifying those areas where this type is a higher priority.

Protection Status Poor in Idaho but Widespread Elsewhere

Mountain brush provides a good example of a vegetation type that is protected poorly in Idaho but well elsewhere (Table 2). This type is widespread throughout the intermountain west, where its northern periphery lies in Idaho. Only slightly greater than 2% is protected in the state. Its status throughout its range is unknown. As in the previous example, a larger-scale ecoregional gap analysis will clarify its status.

Limitations of the Vegetation Analysis

A major limitation of the existing vegetation map is a lack of data on the ecological condition of the vegetation complexes. Gross structural information can be inferred from the map, such as distinctions between forest and shrub-steppe or grassland. Detail is generally lacking, however, within the major physiognomic units. For example, in the forests of the Northern Rocky Mountains, where evidence of fire can be found in virtually every soil profile (Wellner 1970; Steele et al. 1986), there is a wide range of stand ages. Although most of the lodgepole pine forests represent some of this structural variation, these forests comprise less than 20% of the forests. The majority of structural variation remains hidden within the primarily floristic classification. In addition, timber harvest has caused structural diversity in the pattern of forest fragmentation. Much of this is not displayed because of the size of our minimum mapping area of 260 ha. Aspects of horizontal structure, such as variation in canopy cover, are also lacking. These same limitations apply in woodland- and shrub-dominated types as well.

In addition, large areas of Idaho, like much of the arid west, has been heavily affected by livestock grazing. Overgrazing commonly eliminates the native perennial bunchgrasses and forbs, and these areas are now commonly dominated by annual grasses and other weedy species (Yensen 1982).

Those areas in which the shrub cover, such as big sagebrush, was eliminated by repeated burning have been mapped as annual grasslands. Areas which have burned recently do not show up, however, nor do areas in which the shrub cover remains but the understory is in a degraded condition. In our figures, all examples of vegetation within each type are treated as ecological equivalents.

Another limitation, inherent to the methodology itself, is that plant communities that occur in patch sizes less than our minimum mapping unit of 260 ha, but which might otherwise be high-priority conservation targets, are not identified by our study. In fact, conservationists familiar with the ecology of Idaho can readily identify two such types: *Artemisia rigida—Poa secunda* (stiff sage—Sandberg bluegrass), a dwarf-shrub community restricted to basaltic lithosols along the western border of the state, and stands of *Celtis reticulata* (hackberry), a riparian tree species found in small, scattered stands in the canyonlands of southwestern Idaho. Our analysis, however, was designed to identify conservation needs at the regional level, and its shortcomings in this regard serve only to emphasize the need for similar analyses at all levels of ecosystem organization.

Our map of actual vegetation is only a model of the existing vegetation, and all models vary in both accuracy and precision. Both floristic description of the mapping units and boundary placement are fraught with difficulties. The consequent weakness of the model is buffered by the fact that species composition and vegetation boundaries are dynamic throughout space and time.

The data presented here demonstrate an efficient and useful method of assessing the extent and degree of protection of land-cover types and associated biodiversity over an area exceeding 200,000 km^2. Although there are realistic limitations imposed by scale and the difficulties inherent in classifying and mapping vegetation (Kuchler 1973), a consistent and reliable assessment of the conservation status of vegetation is possible. The interpretation of the data, however, must take into consideration not only the numbers but also relevant ecological information concerning the nature and condition of the vegetation and the ecological processes that influence it. Such careful analysis can lead to the identification of unprotected or underprotected vegetation communities. It can also help direct the course of more detailed, local analyses at larger scales and contribute to larger, regional approaches to the assessment of the protection status of biodiversity.

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