

ASSESSING THE EXTENT TO WHICH ROADLESS AREAS COMPLEMENT THE CONSERVATION OF BIOLOGICAL DIVERSITY

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Abstract. We assessed the extent to which inventoried roadless areas (IRAs) on USDA Forest Service lands contain biophysical features that complement the conservation reserve network (e.g., national parks, designated wilderness areas, and wildlife refuges) in the United States. We compared the percentage of land area in IRAs and conservation reserves across three geographic divisions (Alaska, East, and West), 83 ecoregions, 10 elevation zones, and 11 land-cover classes. We also summarized variation in the size class distribution of IRAs.

Of the 83 ecoregions evaluated in the United States, 28 have >12% of their total area in conservation reserves. If IRAs are considered with conservation reserves, the number of ecoregions exceeding the 12% threshold increases from 28 to 32. When only national forest land in the ecoregions is considered, the area of designated wilderness exceeds 12% in 18 of the 45 ecoregions summarized. If IRAs are considered along with designated wilderness, the number of ecoregions exceeding the 12% threshold increases from 18 to 32.

On national forest land below 1500 m, 10% is designated wilderness and 18.5% is IRA. Above 1500 m, 20% is designated wilderness and 31.5% is IRA. If IRAs are considered along with designated wilderness, all land-cover classes (except water in the West) would exceed the 12% threshold in Alaska and the West. In the East, only the evergreen forest class would exceed the 12% threshold when IRAs are considered with designated wilderness.

Of 462 polygons of designated wilderness in the national forests, 353 are <20 250 ha, and 25 areas exceed 101 175 ha. If adjacent IRA land is considered along with national forest wilderness, the number of areas <20 250 ha decreases to 295, and the number of areas >101 175 ha increases to 45.

These results highlight the contribution that IRAs could make toward building a representative network of conservation reserves in the United States. Including these areas as reserves would expand ecoregional representation, increase the area of reserves at lower elevations, and increase the number of areas large enough to provide refugia for species needing large tracts relatively undisturbed by people. Even with the addition of IRAs, many ecoregions in the United States would remain underrepresented in the reserve network, especially in the East.

Key words: biological diversity; ecoregions; elevation zones; land-cover classes; national forests; reserve networks; roadless areas; United States; wilderness.

INTRODUCTION

On 13 October 1999, President Clinton directed the USDA Forest Service to develop regulations to provide long-term protection for inventoried roadless areas (IRAs) on national forest lands (Clinton 1999). IRAs are the remaining roadless areas that were mapped following the passage of the Wilderness Act of 1964. This was done as part of the Roadless Area Review and Evaluation process (RARE I and II; USDA Forest Ser-

vice 1979) and other inventories. Following RARE II, many of these IRAs were designated as wilderness. Many other IRAs were “released” for multiple-use management, whereas others were identified for further study.

Of the 777 000 km² of national forest, ~232 000 km² are IRA and 141 000 km² are congressionally designated wilderness (USDA Forest Service 2000a). IRAs thus include ~30% of national forest lands. Road building is presently prohibited in 94 000 km² of IRAs. The remaining IRAs (138 000 km²) are presently available for multiple-use management and road development.

Representing the full range of habitats in conservation reserves (e.g., national parks, designated wil-

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derness areas, and wildlife refuges) is a fundamental goal of nature conservation (Margules and Usher 1981). In the United States, proposals to establish representative reserves date back at least to 1917 (Shelford 1926). As highlighted in Scott et al. (2001), existing reserves in the United States are concentrated at high elevations and on sites with low soil productivity. As a result, significant elements of biological diversity are probably underrepresented in reserves (Scott et al. 2001). Roadless areas can be valuable as basic units from which to build a reserve network (Noss et al. 1999). It is important to determine the contribution that IRAs could make toward meeting representation needs.

We provide a coarse-scale analysis of the extent to which IRAs contribute to representing biological diversity in the conterminous United States plus Alaska (here, the study area). Regional patterns in the size distribution of IRAs and conservation reserves are also summarized.

METHODS

The distribution of plants and animals is strongly influenced by physical environmental gradients (Whittaker 1967), which are generally specified by radiation, thermal, moisture, nutrient, and biotic regimes (Nix 1982). Here, we used ecoregions as a mapped summarization of biophysical attributes across the United States. In addition to ecoregions, we used mapped elevation classes (derived from a digital elevation model) and land-cover classes (based on satellite imagery) as surrogate indicators of biological diversity. Within an ecoregion, changes in elevation probably reflect local gradients of temperature and precipitation. Specifically, the following geographic information system (GIS) layers were electronically overlaid and summarized to analyze the representation of biological diversity: (1) ecoregions of North America (Gallant et al. [1995] and Omernik [1995], as modified by Ricketts et al. [1999]); (2) elevation classes derived from a national-scale digital elevation model (U.S. Geological Survey 1996); (3) land-cover grid derived from advanced very high-resolution radiometer (AVHRR) imagery (Fleming 1997, USDA Forest Service 1999); (4) land management status (DellaSalla et al. 2001); (5) inventoried roadless areas (USDA Forest Service 2000a); and (6) designated wilderness areas (USDA Forest Service 2000b).

As with almost any GIS database, errors are associated with these layers that transfer into the analytic results. Because land management status and IRA coverages represent a composite of data from many sources, variations in mapping procedures among the sources potentially cause inconsistencies that are difficult to detect in the combined coverages. The land-cover grid undoubtedly contains misclassifications. Variations in area estimates summarized from the overlay analyses result from variations in the resolution of the input

databases and generalization during rasterization. Based on professional judgment, we estimate that the error rate is not large enough to affect conclusions drawn from this national-scale analysis.

Using criteria of species richness, endemism, rare habitats, and rare phenomena, Ricketts et al. (1999) calculated a biological distinctiveness index for each ecoregion, assigning "globally outstanding" status to ecoregions with high biological distinctiveness indices. These ecoregions are highlighted in the ecoregion summary tables.

DellaSalla et al. (2001) assigned each polygon in their GIS coverage of land management status to one of four categories (adapted from Scott et al. 1993): (1) status 1 represents areas strictly managed to maintain natural values (e.g., designated wilderness areas, national parks, and research natural areas); (2) status 2 represents areas managed to maintain natural values (e.g., wildlife refuges); (3) status 3 represents public multiple-use management lands (e.g., national forest lands outside of designated wilderness); (4) status 4 represents lands without active management to maintain natural values. Hereafter, the combination of status classes 1 and 2 is referred to as "conservation reserves."

The following classification scheme was used to categorize national forest IRAs: (1) areas where road building is already prohibited under current Forest Plan decisions; (2) areas where road building and rebuilding are presently allowed. Throughout the text, the combined IRA categories are referred to as total IRA. Each contiguous IRA was treated as a separate and unique IRA.

To evaluate the adequacy of IRAs and conservation reserves to represent biological diversity, we used a threshold of 12% of the total land area in each evaluated category (ecoregion, elevation class, land-cover class). This percentage is based on the recommendation of the World Commission on Environment and Development (1987) that $\geq 12\%$ of a country's land mass be set aside as conservation reserves. The Commission arrived at 12% by suggesting that the amount of land in conservation reserves needed to be at least tripled to achieve a representative sample of biological diversity. In 1987, when the Commission report was published, $\sim 4\%$ of the world was in conservation reserves. In our analysis, 12% is used for comparisons, although it may be too low to be a valid target for representation. For example, based on a review of published studies of the area needed to achieve various conservation goals, Noss and Cooperrider (1994) argue that 25–75% of a region is required to achieve representation. Numerous factors influence the percentage of a region needed in reserves to meet conservation goals. These are listed and described in Noss and Cooperrider (1994: Table 5.2), and include such factors as habitat heterogeneity, area requirements of the species present, scales of natural dis-

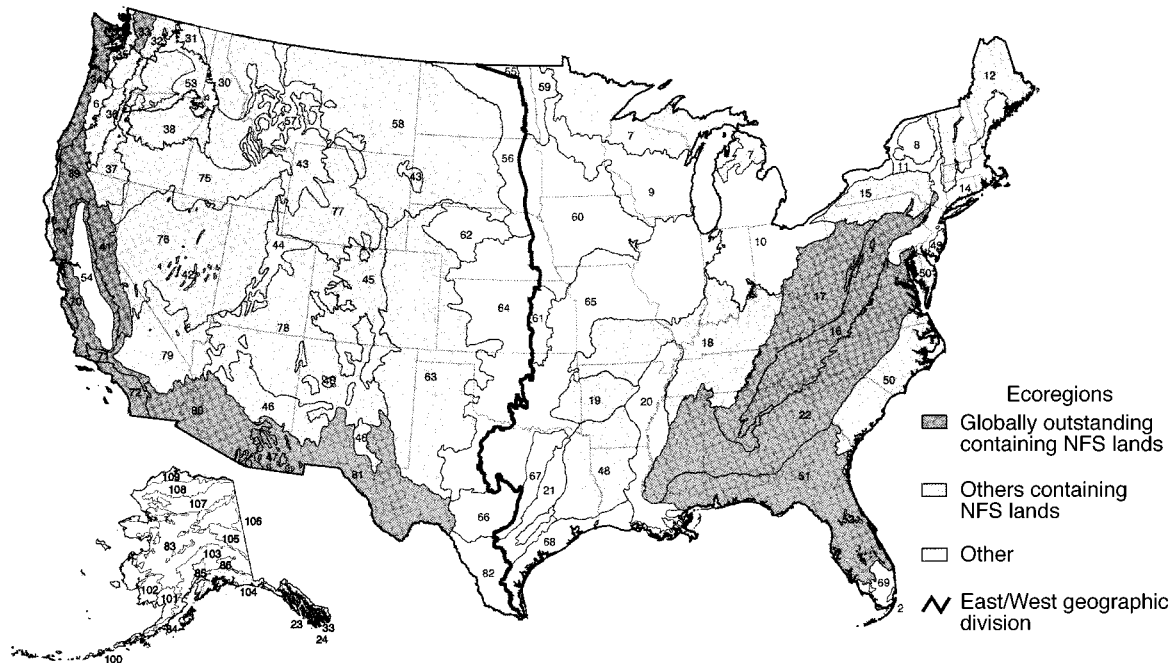


FIG. 1. Terrestrial ecoregions of the conterminous United States plus Alaska as defined by Ricketts et al. (1999). The numbers correspond to ecoregion numbers presented in Table 1. The heavy line in the central portion of the conterminous United States separates the western and eastern geographic divisions. NFS denotes National Forest System.

turbance, and the degree of connectivity among habitat patches.

A map (Fig. 1; see Table 1 for ecoregion names) shows the boundaries and distribution of the 83 ecoregions of the study area (Ricketts et al. 1999). For our summary, these ecoregions were further aggregated into three broad geographic divisions: Alaska, East, and West (Fig. 1).

RESULTS

The total land area of the United States (excluding Hawaii) is 9 235 000 km². According to the database developed by DellaSala et al. (2001), 5% of the area is in status 1, strictly managed to maintain natural values; 5% is status 2, managed to maintain natural values; 21% is status 3, multiple-use management; and 69% is status 4, no active management to maintain natural values. On a broad geographic basis (Table 1), the combined percentage in status classes 1 and 2 ("conservation reserves") varies from a high of 36% in Alaska, to 7% in the West, and 2% in the East. When Alaska is excluded, only ~5% of the United States is conservation reserves, much lower than the recommended 12% minimum and an order of magnitude less than the midpoint of the range suggested by Noss and Cooperrider (1994).

To put the roadless area analysis into context, the total IRA area of 232 000 km² represents only 2.5% of the land of the study area. When only those IRAs where current management prescriptions allow roads are con-

sidered, only 1.5% (138 000 km²) of the study area is included.

On a broad geographic basis (Table 1), the total IRA is 54 400 km² (3.7% of the land area) in Alaska, 171 000 km² (4.0%) in the West, and 6600 km² (0.2%) in the East. When only the IRA category that currently allows roads is considered, the total area included is 17 600 km² (1.2%) in Alaska, 116 200 km² (2.8%) in the West, and 4100 km² (0.1%) in the East.

Ecoregions

Of the 83 ecoregions in the study area (Fig. 1), 28 (representing ~24% of the total land area) have >12% of their area in conservation reserves (Table 1). The distribution of these 28 ecoregions is uneven across the study area, with 14 in Alaska, 12 in the West, and only two in the East. In Alaska, the only ecoregion with <12% of its area in conservation reserves is the Arctic Coastal Tundra (2% in conservation reserves). The only ecoregions in the East with >12% of their area in conservation reserves are the Forest/Boreal Transition (33%, primarily in the Adirondacks of New York) and the Everglades (50%).

If the total IRA is added to the conservation reserves, the number of ecoregions exceeding the 12% threshold increases to 32 (Table 1), representing ~28% of the total land area. All four of these additional areas are in the West (Blue Mountains, Wasatch/Uinta Montane, Colorado Rockies, and Arizona Mountains).

For the 23 ecoregions considered globally outstand-

TABLE 1. Percentage of land area in conservation reserves and inventoried roadless areas (IRA), by ecoregion (see Fig. 1). The 23 globally outstanding (go) ecoregions are indicated.

Ecoregion	Total area (km ²)	Percentage of area classified as:				
		Reserves [‡]	Reserves + total IRA [§]	Reserves + "roads allowed" [¶] IRA [§]	Total IRA increase	"Roads allowed" IRA increase ^{¶¶}
Name and number [†]						
Alaska geographic division						
Northern Pacific Coast (23, go)	51 000	19	64	35	232	31
Icefields and Tundra (104)	105 000	37	66	46	79	17
Interior Alaska Taiga (83)	405 000	31	31	31	0	0
Alaska Peninsula Taiga (84)	43 000	73	73	73	0	0
Cook Inlet Taiga (85)	28 000	14	14	14	0	0
Copper Plateau Taiga (86)	17 000	24	24	24	0	0
Aleutian Islands Tundra (100, go)	4 000	64	64	64	0	0
Beringia Lowland Tundra (101)	147 000	53	53	53	0	0
Beringia Upland Tundra (102)	96 000	35	35	35	0	0
Alaska/St. Elias Range (103)	145 000	40	40	40	+	0
Alaska Alpine Tundra (105)	115 000	24	24	24	0	0
Ogilvie Alpine Tundra (106)	11 000	31	31	31	0	0
Brooks Range Tundra (107)	134 000	69	69	69	0	0
Arctic Foothills Tundra (108, go)	124 000	18	18	18	0	0
Arctic Coastal Tundra (109, go)	49 000	2	2	2	0	0
Eastern geographic division						
Western Great Lakes (7)	200 000	4	4	4	7	7
New England/Acadia (12)	118 000	2	3	3	37	15
Allegheny Highlands (15)	84 000	3	3	3	5	+
Appalachian/Blue Ridge (16, go)	159 000	3	5	4	58	22
Mixed Mesophytic (17, go)	192 000	1	1	1	13	11
Central U.S. Hardwoods (18)	296 000	1	1	1	3	3
Ozark Mountains (19)	62 000	2	3	3	34	26
Southeastern Mixed Forests (22, go)	347 000	+	+	+	1	1
Piney Woods (48)	141 000	1	1	1	1	1
Middle Atlantic Coast (50)	130 000	3	3	3	2	2
Southeastern Conifer (51, go)	233 000	3	3	3	3	1
Florida Sand Pine Scrub (52, go)	4 000	6	6	6	6	6
Northern Tall Grasslands (59)	42 000	1	1	1	53	53
South Florida Rocklands (2)	2 000	8	8	8	0	0
Forest/Boreal Transition (8)	29 000	33	33	33	0	0
Forest/Savanna Transition (9)	166 000	1	1	1	0	0
Southern Great Lakes (10)	220 000	1	1	1	0	0
Great Lakes Lowlands (11)	25 000	1	1	1	0	0
Northeastern Coast (14)	88 000	2	2	2	0	0
Mississippi Lowlands (20)	112 000	2	2	2	0	0
East Central Texas (21)	53 000	+	+	+	0	0
Pine Barrens (49)	9 000	8	8	8	0	0
Aspen Parklands (55)	6 000	1	1	1	0	0
Central Tall Grasslands (60, go)	249 000	+	+	+	0	0
Flint Hills Tall Grasslands (61, go)	30 000	+	+	+	0	0
Forest/Grassland Transition (65)	407 000	+	+	+	0	0
Texas Blackland Prairies (67)	50 000	+	+	+	0	0
Gulf Coast Grasslands (68)	73 000	1	1	1	0	0
Everglades (69, go)	20 000	50	50	50	0	0
Western geographic division						
North Central Rockies (30)	102 000	21	38	32	85	42
Okanogan Forests (31)	14 000	1	5	4	516	318
Cascade Mnts. Leeward (32)	16 000	34	55	40	63	12
North Cascades (33, go)	14 000	31	42	33	36	5
Central Pacific Coastal (34, go)	40 000	7	8	7	17	4
Puget Lowlands (35)	16 000	+	+	+	78	78
Central/South. Cascades (36)	45 000	17	24	19	41	12
Eastern Cascades (37)	55 000	4	7	6	79	40
Blue Mountains (38)	65 000	7	13	11	90	42
Klamath-Siskiyou (39, go)	50 000	13	22	17	75	26
Northern California Coast (40, go)	13 000	9	10	9	2	+
Sierra Nevada (41, go)	53 000	29	37	34	28	14
Great Basin Montane (42)	6 000	19	53	49	173	126
South Central Rockies (43)	160 000	27	55	47	105	55

TABLE 1. Continued.

Ecoregion	Name and number†	Total area (km ²)	Percentage of area classified as:				
			Reserves‡	Reserves + total IRA§	Reserves + "roads allowed" IRA§	Total IRA increase	"Roads allowed" IRA increase¶
Wasatch/Uinta Montane (44)		42 000	7	38	33	416	226
Colorado Rockies (45)		133 000	12	27	23	124	76
Arizona Mountains (46)		109 000	9	15	12	68	27
Madrean Sky Islands (47, go)		11 000	15	30	15	98	+
Palouse Grasslands (53)		47 000	2	3	3	28	25
Montana Valley/Foothill (57)		67 000	3	5	5	92	73
NW Mixed Grasslands (58)		506 000	1	1	1	27	23
West. Short Grasslands (63)		435 000	+	+	+	6	+
Central California Shrub/Savanna (70, go)		64 000	6	8	7	31	21
Southern California Woods/Shrub (71, go)		20 000	20	36	31	83	44
Southern California Coastal Scrub (72, go)		24 000	9	11	10	30	11
Snake/Colorado Shrub Steppe (75)		219 000	3	4	4	23	16
Great Basin Shrub Steppe (76)		336 000	3	8	8	157	129
Wyoming Basin (77)		133 000	1	2	2	55	52
Colorado Plateau (78)		327 000	7	8	8	13	11
Mojave Desert (79)		131 000	33	33	33	1	1
Sonoran Desert (80, go)		117 000	17	17	17	+	+
Chihuahuan Deserts (81, go)		205 000	8	8	8	2	1
Willamette Valley (6)		15 000	+	+	+	0	0
California Central Valley (54)		55 000	2	2	2	0	0
Northern Mixed Grasslands (56)		109 000	1	1	1	0	0
Nebraska Sand Hills (62)		61 000	1	1	1	0	0
Central/Southern Grasslands (64)		282 000	0	0	0	0	0
Edwards Plateau (66)		62 000	+	+	+	0	0
Tamaulipan Mezquital (82)		57 000	0	0	0	0	0

Notes: Total area values are rounded to the nearest 1000 km², and percentages are rounded to the nearest whole number. Values greater than zero but less than 0.5% are coded as +.

† Ecoregion delineations and the globally outstanding assignments are from Ricketts et al. (1999).

‡ Combined status 1 and status 2 data from DellaSala et al. (2001).

§ IRA data from USDA Forest Service (2000a).

|| Total IRA increase = 100 × total IRA area/conservation reserve area.

¶ "Roads allowed" IRA increase = 100 × "roads allowed" IRA area/(conservation reserve area + "roads prohibited" IRA area).

ing by Ricketts et al. (1999), if total IRA is included, the total area for nine of them increases above that in conservation reserves by >20% (Table 1). These ecoregions are the Northern Pacific Coast in Alaska, the Appalachian/Blue Ridge in the East, and the North Cascades, Klamath-Siskiyou, Sierra Nevada, Madrean Sky Islands, Central California Shrub/Savanna, Southern California Woods/Shrub, and Southern California Coastal Scrub in the West.

Forty-five ecoregions contain IRA land and >40 470 ha each of national forest (Table 2). Of these, 30 have total IRA area in excess of 20% of the land area currently in conservation reserves (Table 1). Two are in Alaska, 24 are in the West, and four are in the East. Ecoregions with increases exceeding 100% are Okanogan Forests, Wasatch/Uinta Montane, Northern Pacific Coast, Great Basin Montane, Great Basin Shrub Steppe, Colorado Rockies, and South Central Rockies.

Considering only those 45 ecoregions containing national forest lands, designated wilderness exceeds the 12% threshold in 18 of them (Table 2). If the total IRA area is considered along with designated wilderness, the number of ecoregions exceeding the 12% threshold

increases to 32; 10 of the 13 ecoregions that remain below the 12% threshold are in the East.

Finally, of the 16 globally outstanding ecoregions containing IRA and >40 470 ha of national forest (Table 2), eight have >12% of their national forest area in designated wilderness. If total IRA area is considered along with designated wilderness, the number of globally outstanding ecoregions exceeding the 12% threshold (considering national forest lands only) increases to 11. The five ecoregions with less than the 12% threshold are all in the East.

Elevation class

The distribution of IRA and designated wilderness with elevation on national forest lands is summarized in Table 3. More land is IRA at lower elevations on the national forest than is designated wilderness. Below 1500 m, 10% of national forest lands in the study area is designated wilderness and 18.5% is IRA. At elevations above 1500 m, 20% of national forest lands is designated wilderness and ~31.5% is IRA.

In Alaska, designated wilderness exceeds 12% of the area in all elevation classes below 2100 m. At eleva-

TABLE 2. Percentage of national forest area in designated wilderness and inventoried roadless areas (IRA), by ecoregion (see Fig. 1). Globally outstanding (go) ecoregions are indicated.

Ecoregion	Total area (ha)	Percentage of area classified as:				
		Wilderness [‡]	Wilderness + total IRA [§]	Wilderness + "roads allowed" [¶] IRA [§]	Total IRA increase	"Roads allowed" ^{¶¶} IRA increase ^{¶¶}
Name and number [†]						
Alaska geographic division						
Northern Pacific Coast (23, go)	4 446 000	25	69	42	175	34
Icefields and Tundra (104)	4 322 000	21	79	44	267	41
Eastern geographic division						
Western Great Lakes (7)	4 405 000	11	12	12	12	12
New England/Acadia (12)	596 000	11	28	20	147	44
Allegheny Highlands (15)	306 000	1	2	1	55	8
Appalachian/Blue Ridge (16, go)	3 772 000	4	12	8	200	53
Mixed Mesophytic (17, go)	1 861 000	2	4	4	78	64
Central U.S. Hardwoods (18)	1 940 000	2	3	3	38	32
Ozark Mountains (19)	1 424 000	3	6	6	92	64
Southeast Mixed Forests (22, go)	1 251 000	+	+	+	49	49
Piney Woods (48)	1 164 000	2	2	2	8	8
Middle Atlantic Coast (50)	288 000	6	9	9	48	41
Southeastern Conifer (51, go)	799 000	4	6	5	54	25
Florida Sand Pine Scrub (52, go)	102 000	4	5	5	33	33
Northern Tall Grasslands (59)	55 000	0	34	34	+++	+++
Western geographic division						
North Central Rockies (30)	6 953 000	20	47	36	135	52
Okanogan Forests (31)	325 000	0	17	16	+++	1420
Cascade Mnts. Leeward (32)	1 281 000	37	56	44	50	13
North Cascades (33, go)	724 000	43	65	47	50	7
Central Pacific Coastal (34, go)	687 000	5	12	7	134	18
Central/Southern Cascades (36)	2 804 000	19	30	23	54	16
Eastern Cascades (37)	3 077 000	2	8	6	238	90
Blue Mountains (38)	2 726 000	15	28	23	93	42
Klamath-Siskiyou (39, go)	2 810 000	20	34	27	74	28
Sierra Nevada (41, go)	3 616 000	21	32	27	54	26
Great Basin Montane (42)	389 000	29	80	74	179	132
South Central Rockies (43)	11 319 000	24	63	52	159	76
Wasatch/Uinta Montane (44)	2 813 000	9	54	48	481	249
Colorado Rockies (45)	7 652 000	19	44	38	133	83
Arizona Mountains (46)	6 340 000	12	23	18	89	34
Madrean Sky Islands (47, go)	608 000	20	44	20	119	+
Palouse Grasslands (53)	171 000	7	20	19	196	156
Montana Valley/Foothill (57)	526 000	2	33	29	1637	494
NW Mixed Grasslands (58)	2 858 000	+	6	5	5050	762
West. Short Grasslands (63)	1 274 000	0	+	+	+++	+
Central California Shrub/Savanna (70, go)	441 000	9	33	28	277	137
Southern California Woods/Shrub (71, go)	1 185 000	32	61	51	89	46
Southern California Coastal Scrub (72, go)	295 000	14	34	23	151	37
Snake/Colorado Shrub Steppe (75)	520 000	1	34	25	2686	244
Great Basin Shrub Steppe (76)	3 282 000	9	60	56	602	380
Wyoming Basin (77)	241 000	3	38	37	1414	901
Colorado Plateau (78)	1 323 000	6	28	26	347	211
Mojave Desert (79)	172 000	23	28	26	20	12
Sonoran Desert (80, go)	78 000	25	35	28	41	10
Chihuahuan Desert (81, go)	137 000	5	30	16	531	56

Notes: Total area values are rounded to the nearest 1000 ha, and percentages are rounded to the nearest whole number. Values greater than zero but less than 0.5% are coded as +. Some of the increase values are infinitely large because the denominator is zero. These values are area coded as +++.

[†] Ecoregion delineations and globally outstanding (go) assignments are from Ricketts et al. (1999).

[‡] Designated wilderness data from USDA Forest Service (2000b).

[§] IRA data from USDA Forest Service (2000a).

^{||} Total IRA increase = $100 \times \text{total IRA area}/\text{designated wilderness area}$.

^{¶¶} "Roads allowed" IRA increase = $100 \times \text{"roads allowed" IRA area}/(\text{designated wilderness area} + \text{"roads prohibited" IRA area})$.

tions above 600 m, ~96% of the land area is included when total IRA area is considered along with designated wilderness. Below 600 m, ~79% of the area is included. In the East, designated wilderness exceeds 12% of elevation zone area in only the 1501–1800 m zone (23%). When IRA is considered along with designated wilderness, only the 0–300 and 301–600 m elevation zones do not exceed the 12% threshold. The area of designated wilderness exceeds that of IRA below 600 m and between 1501 and 1800 m. In the West, designated wilderness exceeds 12% of elevation zone area in all elevation zones above 1500 m. When IRA is considered along with designated wilderness, only the 0–300 m elevation zone does not exceed the 12% threshold. Total IRA area exceeds designated wilderness across all elevation classes from sea level to 2700 m.

Land-cover class

The distribution of IRA and designated wilderness by land-cover class on national forest lands is summarized in Table 4.

In Alaska, designated wilderness exceeds 12% of the area in five of eight land-cover classes. IRAs represent ~74% of the combined area of deciduous forests, mixed forests, and shrublands, but only ~9% of the area in these land-cover classes is contained in designated wilderness. Total IRA area exceeds designated wilderness in all land-cover classes. In the East, if total IRA area is considered with designated wilderness, representation of the evergreen class would exceed the 12% threshold. None of the other seven land-cover classes would be represented above the 12% threshold. In the West, designated wilderness exceeds 12% of the area in three of eight land-cover classes. If IRA area is considered with designated wilderness, seven of the eight land-cover classes would exceed the 12% threshold. Only the water class would remain below the threshold.

Size class distribution

The number and total area of IRAs in Alaska, the East, and the West are shown in Fig. 2. Most IRAs >200 ha are <10 125 ha (2554 areas totaling 7 500 000 ha), and 26 areas totaling 6 352 000 ha exceed 101 175 ha (Fig. 2a). The West has the most (2496 areas) IRAs >200 ha; the East has 244, and Alaska has 269 (Fig. 2a).

If only those IRAs where road building is already prohibited are considered, areas >200 ha but <10 125 ha total 1522 areas across 3 187 000 ha and 11 areas totaling 2 832 000 ha exceed 101 175 ha (Fig. 2b).

About 8 126 000 ha of IRA in the study area are adjacent to designated wilderness (~14 000 000 ha; Table 5). This represents 35% of the total IRA area. There are 392 designated wilderness areas on the national forests. Based on the GIS database (USDA Forest Service 2000b), these 392 areas consist of 462 discrete

TABLE 3. Percentage of national forest lands within inventoried roadless areas and designated wilderness by elevation class and geographic division.

Elevation (m)	Total area (ha)	Percentage of national forest lands within:		
		Total IRA [†]	“Roads allowed” IRA [†]	Designated wilderness [‡]
Alaska geographic division				
0–300	3 282 000	53	17	20
301–600	2 136 000	61	22	25
601–900	1 366 000	69	24	26
901–1200	1 011 000	72	24	25
1201–1500	615 000	74	20	24
1501–1800	238 000	71	15	27
1801–2100	69 000	80	11	18
2101–2400	25 000	88	10	11
2401–2700	14 000	99	4	1
>2700	12 000	98	3	0
Eastern geographic division				
0–300	7 869 000	1	1	2
301–600	7 312 000	3	2	8
601–900	2 108 000	11	6	5
901–1200	997 000	14	8	8
1201–1500	180 000	15	11	11
1501–1800	22 000	20	16	23
>1800	1 000	36	26	7
Western geographic division				
0–300	478 000	8	2	4
301–600	1 343 000	14	7	8
601–900	4 643 000	14	9	8
901–1200	6 205 000	15	9	10
1201–1500	9 735 000	15	9	10
1501–1800	9 733 000	20	12	15
1801–2100	9 872 000	30	20	17
2101–2400	9 305 000	37	28	16
2401–2700	6 866 000	39	30	18
>2700	8 610 000	33	23	36

Note: Total area values are rounded to the nearest 1000 ha, and percentages are rounded to the nearest whole number.

[†] IRA data from USDA Forest Service (2000a).

[‡] Designated wilderness data from USDA Forest Service (2000b).

polygons >200 ha. Most designated wilderness areas >200 ha on the national forests are <20 250 ha (353 areas totaling 2 139 000 ha), and only 25 areas totaling 7 822 000 ha exceed 101 175 ha (Fig. 3a). If all IRAs adjacent to wilderness are considered with designated wilderness, the number of areas >200 ha but <20 250 ha decreases to 295 (1 838 000 ha), and the number of areas >101 175 ha increases to 45 (15 913 000 ha). Of these largest areas, 10 are in Alaska, 34 are in the West, and one (Boundary Waters Canoe Area Wilderness) is in the East.

When IRAs separate from designated wilderness are considered in addition to the merged IRA/wilderness areas, there are 2435 areas (totaling 10 055 000 ha) <20 250 ha but >200 ha (Fig. 3b), and 57 areas >101 175 ha (totaling 19 020 000 ha). Of these largest areas, 16 are in Alaska, 40 are in the West, and one is in the East.

TABLE 4. Percentage of national forest lands within inventoried roadless areas (IRA) and designated wilderness by land-cover class and geographic division.

Land-cover class [†]		Percentage of national forest lands within:		
		Total IRA [‡]	"Roads allowed" [‡] IRA [‡]	Designated wilderness [§]
Name and number	Total area (ha)			
Alaska geographic division				
Deciduous Forest (1)	500	90	70	0
Evergreen Forest (2)	4 652 000	54	18	23
Mixed Forest (3)	1 000	46	13	0
Shrub/Brush (4)	448 000	74	53	9
Tundra (7)	35 000	66	23	15
Barren Land (9)	1 598 000	59	18	37
Water (10)	63 000	51	19	23
Glaciers-Snow (11)	1 970 000	82	19	15
Eastern geographic division				
Deciduous Forest (1)	9 804 000	4	2	3
Evergreen Forest (2)	4 778 000	3	2	10
Mixed Forest (3)	2 478 000	4	2	3
Shrub/Brush (4)	1 000	0	0	0
Rangeland (5)	1 000	0	0	0
Wetland (6)	3 000	0	0	0
Undifferentiated Shrub/Grass (8)	1 098 000	4	3	1
Water (10)	327 000	1	1	8
Western geographic division				
Deciduous Forest (1)	3 181 000	31	26	10
Evergreen Forest (2)	48 624 000	26	17	18
Shrub/Brush (4)	6 403 000	25	18	12
Rangeland (5)	3 784 000	11	10	3
Tundra (7)	1 132 000	22	11	61
Undifferentiated Shrub/Grass (8)	3 402 000	26	20	9
Barren (9)	36 000	40	40	10
Water (10)	229 000	6	3	2

Note: Total area values are rounded to the nearest 1000 ha, and percentages are rounded to the nearest whole number.

[†] Derived from Fleming (1997) and USDA Forest Service (1999).

[‡] IRA data from USDA Forest Service (2000a).

[§] Designated wilderness data from USDA Forest Service (2000b).

DISCUSSION

The results highlight the contribution that IRAs could make to building a representative network of conservation reserves in the United States. Including IRAs as conservation reserves would expand ecoregional representation, increase the area of conservation reserves at low, often more biologically productive, elevations, and increase the number of areas large enough to provide refugia for species that require large tracts relatively undisturbed by humans.

The IRAs greatly increase the percentage of ecoregions where the area of conservation reserves on national forest lands exceeds the 12% threshold. When designated wilderness is considered alone, 40% of the ecoregions exceed the 12% threshold. When IRA is considered with designated wilderness, 71% of the ecoregions exceed the 12% threshold. Even with the addition of IRAs, however, many ecoregions in the United States would remain underrepresented in the network, especially in the East. Our results suggest a need to pursue opportunities for ecological restoration in the East to more fully conserve biological diversity

there. We also suggest extending the analysis of roadless areas to other federal lands (in addition to USDA Forest Service lands), and suggest that these areas be considered for possible inclusion in a conservation reserve network.

A general misconception persists that IRAs are predominantly at high elevations in rocky and cold habitats. On the national forests, however, more land below 1500 m is IRA than designated wilderness. Maintaining the natural values of these roadless areas would reduce the underrepresentation of low-elevation sites in conservation reserves, as highlighted by Scott et al. (2001). Further, in addition to rocky lands, a full range of land cover types including forest, shrub, and herbaceous land types is represented in the IRAs.

Biological diversity is positively related to the size of a conservation reserve (MacArthur and Wilson 1967). Large areas generally contain more species, more species with large home ranges, and more species sensitive to human activity. Ecosystem processes are generally more intact in larger areas. Small areas remain important in conservation strategies for main-

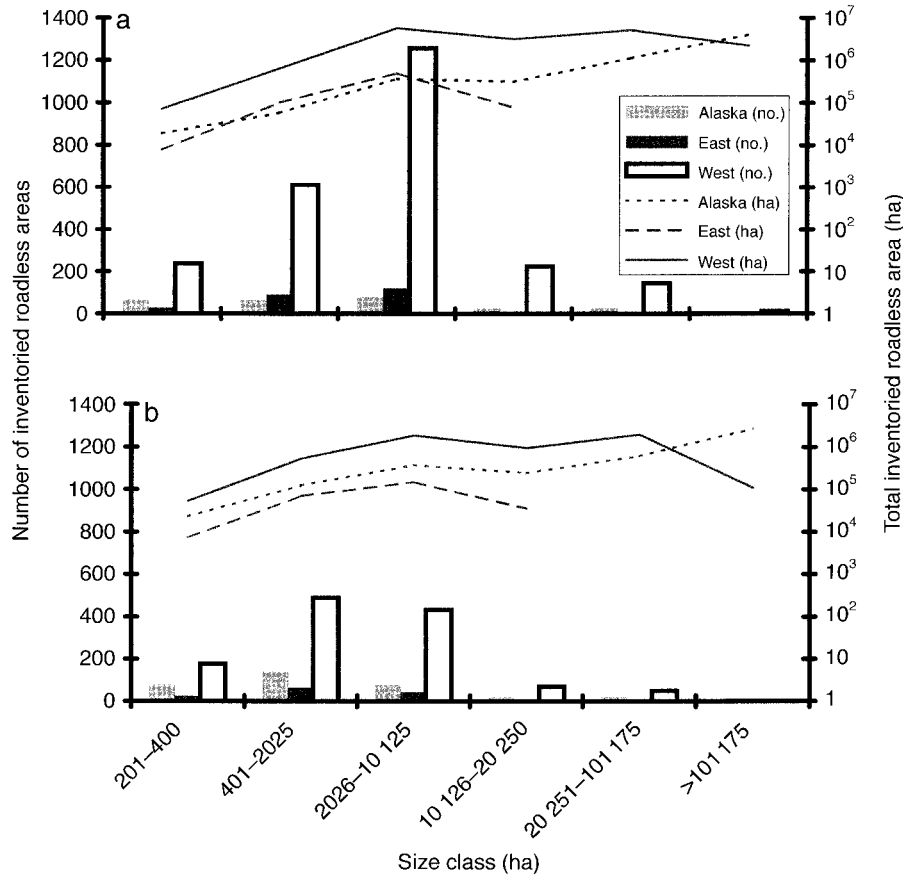


FIG. 2. Number and total area, by size class, of inventoried roadless areas (IRA; USDA Forest Service 2000a) in Alaska and the eastern and western geographic divisions that are >200 ha in (a) total IRA and (b) IRA where roads are already prohibited.

taining biological diversity because they may be species rich, may contain species with special habitat needs, or may provide stepping-stones linking larger areas (Shafer 1995).

Over one-third of the IRA is adjacent to designated wilderness areas. Maintaining these roadless areas would have great value in supporting populations of species that need large, contiguous blocks of relatively undisturbed habitat.

We see this analysis as a first step toward a national summary of IRAs in the context of conserving biological diversity. Our analysis includes methods similar to those of the Alaska-wide assessment of terrestrial biological diversity described by Duffy et al. (1999). Both studies use coarse-scale surrogates for biological diversity, including ecoregions and land-cover types. As Duffy et al. (1999) point out, using coarse surrogates may not adequately represent the location and

TABLE 5. Total area and percentage of area of designated wilderness plus adjacent inventoried roadless areas (IRA) on national forest lands, by geographic division within the conterminous United States plus Alaska.

Geographic division	Designated wilderness	IRA excluding "roads allowed"			IRA including "roads allowed"		
		Adjacent (ha)	Grand total (ha)	Adjacent: grand total (%)	Adjacent (ha)	Grand total (ha)	Adjacent: grand total (%)
Alaska	2 315 000	1 675 000	3 663 000	46	2 286 000	5 420 000	42
East	813 000	49 000	252 000	19	186 000	651 000	29
West	10 893 000	1 872 000	5 339 000	35	5 654 000	16 885 000	33
Total	14 021 000	3 596 000	9 253 000	39	8 126 000	22 956 000	35

Notes: Area values are rounded to the nearest 1000 ha, and percentages are rounded to the nearest whole number. Designated wilderness data are from the USDA Forest Service (2000b); IRA data are from the USDA Forest Service (2000a).

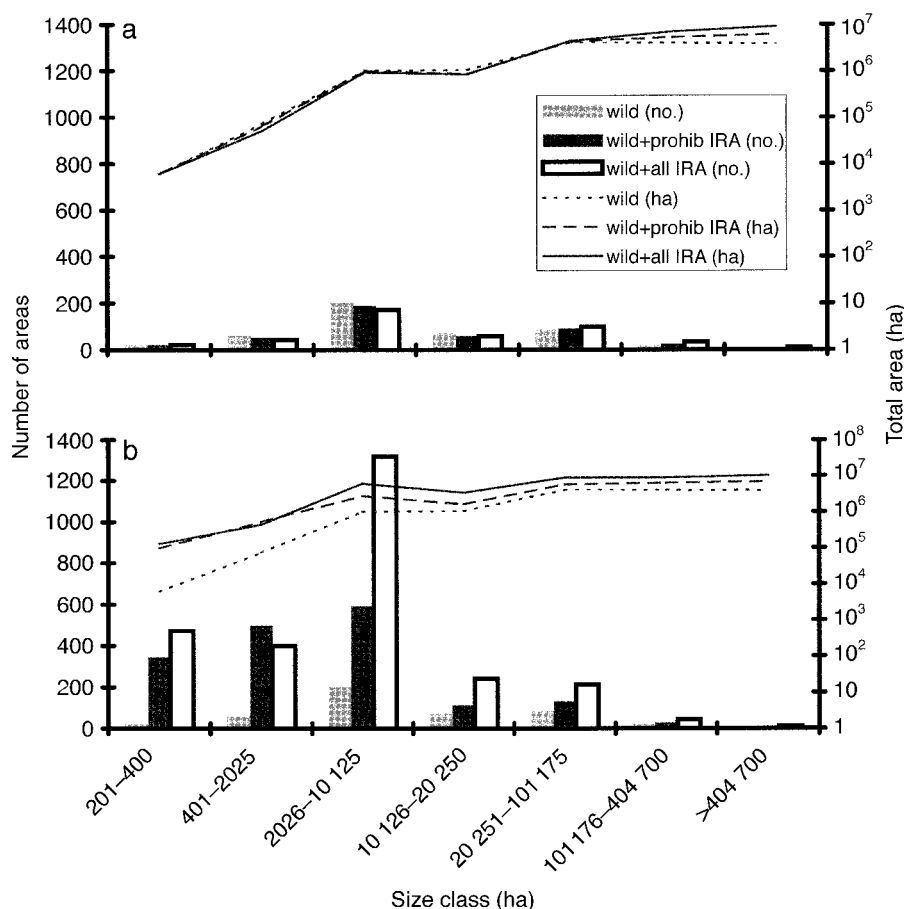


FIG. 3. Number and total area of designated wilderness areas (USDA Forest Service 2000b) and inventoried roadless areas (IRA, USDA Forest Service 2000a) >200 ha in the conterminous United States plus Alaska in (a) designated wilderness plus adjacent IRA, and in (b) designated wilderness plus IRA (without adjacency restriction).

range of biologically important sites. For example, having a large portion of an ecoregion in conservation reserves does not ensure that the range of biological diversity in that ecoregion is also in reserves. The distribution of many of the species may reflect ecological conditions operating at finer scales than conditions depicted by broad ecoregions, elevation classes, and land-cover types.

A more in-depth analysis is desirable, from which a national biological diversity conservation strategy could be built. A promising avenue for such analysis would be a national synthesis of the vegetation and species distribution data contained in the Gap Analysis Project databases (Scott et al. 1993). A repeatable, computer-based technique for identifying representative reserves (Bedward et al. 1992, Davis et al. 1996, Kiestler et al. 1996) could then be used to rigorously quantify the extent to which IRAs and conservation reserves contain the range of biological diversity.

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